JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

VOL. 29 JUNE, 1937 No. 6

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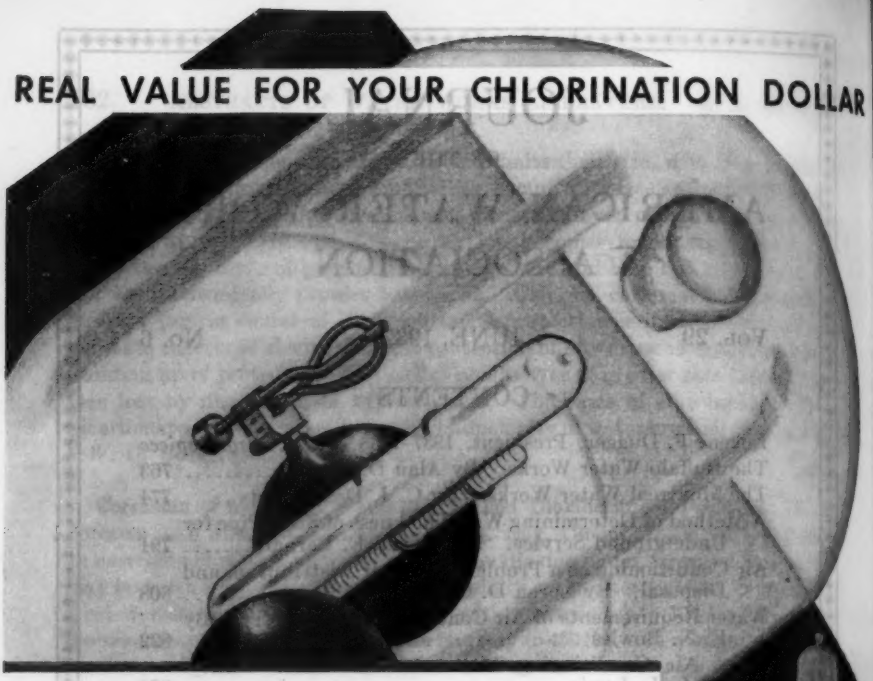

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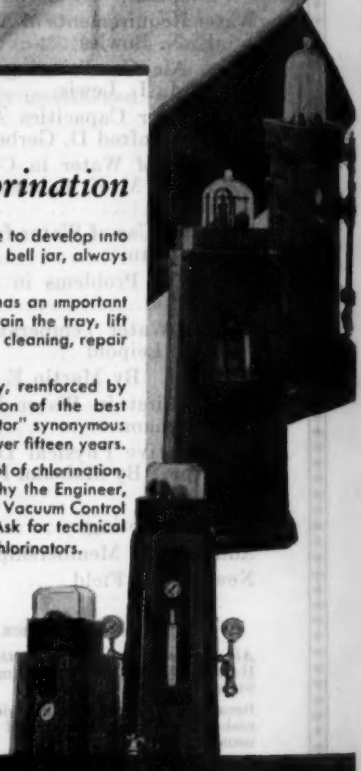

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Discussion of all papers is invited

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THE BUFFALO WATER WORKS*

BY ALAN D. DRAKE

(Director of Water, Buffalo, N. Y.)

There is always some physiographic condition which is the original motive for the establishment of a community and, usually, is responsible for whatever economic prosperity that community eventually attains. Buffalo's commercial and industrial growth has been largely dependent upon its proximity to large bodies of water and upon the development of the advantages which such a favorable position presented. The physical and chemical characteristics which, at first, offered a clean, odorless, tasteless and, above all abundant water for human consumption have been, in a great measure, responsible for Buffalo's industrial status.

However, the hypothesis of abundant water became so firmly established in the minds of Buffalo's first settlers that, handed as a heritage to their descendants it had, from the founding of the water works and for ninety years after, given Buffalo the doubtful distinction of leading all other large American cities in wastefulness and extravagance in the use of a water supply. This enormous capacity for the consumption of water has been, through the years, the outstanding feature of the system, the cause for many years of exaggeration in its size and in that of its appurtenances, the subject of innumerable references in water works periodicals and literature and

*Presented before the Buffalo convention, June, 1937.

the object to which the management of other water works pointed a pharisaic finger.

FIRST WATER PLANT

These people of abnormal thirst established their first water system, having wooden pipes as distributors and springs as a source, 111 years ago. Twenty-six years later, in 1852, water was first pumped from the Niagara River and an eleven million gallon reservoir was added to the system. In 1868 the State Legislature authorized the city to issue bonds and to acquire the entire property of the original private company, on which there were then 34 miles of pipe.

The populating of the higher ground in the city and the improvement in pumping machinery led, in 1872, to the establishment of the dual pressure service which, although continually the object of much criticism, was to persist for 64 years.

Soon after the purchase of the works the Water Board was amazed to find that the, then, 80 gallon per capita was increasing at an alarming rate and in their annual report of 1874 recommended that wanton and illegal use of water should be penalized. But they met the increasing demand by making an unfortunate choice in the selection of a site for, and the construction of, a new intake in the Niagara River about one mile below Lake Erie. Benevolently it must be said of the location that the sanitary relations of the domestic water supply were not then understood and the pollution of the river later developed with the growth of the city and the installation of sewers.

In the same year land was purchased on which to build a reservoir as a reinforcement for the low pressure service. The placing of meters on a few supplies was hailed as holding the potential solution to the high pumpage problem, a promise that was not to be fulfilled as the per capita later mounted to 350 gallons per day and meters, in Buffalo never attained much popularity as a means of measuring domestic consumption.

The decade following 1884 was a period of growth, development and progress for the city. In consequence 256 miles of pipe were added to the system and the consumption increased from 24 million gallons to 80 million gallons a day.

The construction of the reservoir had been delayed twenty years because of the growth in area, and in importance, of the high pressure zone and an increasing doubt as to its practicability. However, in lieu of enlarged pumping capacity and on account of great irregu-

larity in the delivered pressure, the reservoir was completed and placed in service in 1894. It had a capacity of 116,000,000 gallons and was intended to supply three-fourths of the city with pressure ranging from 15 to 35 lbs. per square inch. The completion of the reservoir definitely committed Buffalo to the dual pressure system.

In 1896 it was realized that frequent trouble caused by clogging of the intake ports by ice and excessive turbidity of the supply were, in a great degree, due to the location of the intake in the Niagara River. Expert advice was sought and produced the recommendation that the intake should be replaced by one in, or near, the lake and that a filtration plant be added, one having been successfully operated at Poughkeepsie, N. Y. since 1872.

Buffalo pioneered in 1897 in being one of the first cities in the United States to protect its congested value district by means of a high pressure fire system. It originally consisted of 6,130 feet of 12 inch pipe and was supplied by two fire boats with a capacity of 10,000 gallons per minute.

Due to the prevalence and mortality of typhoid fever in 1902 suspicion was cast upon the water supply as acting as a vehicle for the transmission of disease. Once more attention was focused on the intake still located in the swift moving Niagara River where it was not free from local pollution. Many schemes of amelioration were advanced and seriously considered such as, the construction of an immense, ten day supply, suction reservoir and sedimentation basin in the lake; an intake and high service reservoir 10 miles south of the city and a filtration plant. Had it not been for the excessive cost of filtering an over large consumption, Buffalo would have had its filtration plant at this time. Finally, as a dictate of economy, a site for a new intake was chosen at the head of the Niagara River at a point where difficulties from ice would be diminished and the lake, acting as a settling basin, it was hoped, that pollution and turbidity would be greatly decreased.

In 1906 the Massachusetts Avenue Pumping Station, then fifty-six years old, was rebuilt. It had an enlarged capacity of 227 million gallons, to supply a city of 395,000. The Water Board boasted, with much pride, that it was the largest pumping station in the world. A sad commentary on the ability to cope with the problem of reducing a pumpage that was at least twice as large as was necessary.

The high pressure zone was spreading rapidly to the northeastern extremity of the city and pressure regulation was extremely poor in

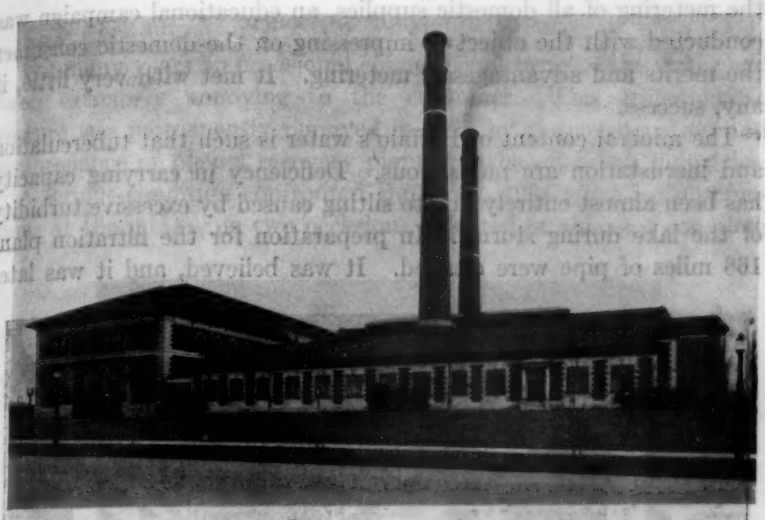
that section. As there was no natural elevation of sufficient height to produce the required pressure, a high service reservoir was out of the question. It was decided to extend large feeders into this part of the city and to reduce pressure fluctuations by means of a standpipe. This standpipe, known as Kensington Tower, was built in 1909 and has a capacity of 704,970 gallons, very little of which is available for storage. Its action is mostly that of an equalizer and, for many years, the operation of the high pressure pumps were regulated by the height of water in this standpipe.

Nearly twenty years after it was first suggested as a panacea for the ills that beset the system, all of the water pumped into it was, in 1913, taken from the Emerald Channel intake and, shortly after, the supply was sterilized by chlorination. Since that time the Niagara River intake has been held as an emergency reserve in the event of failure of the newer intake.

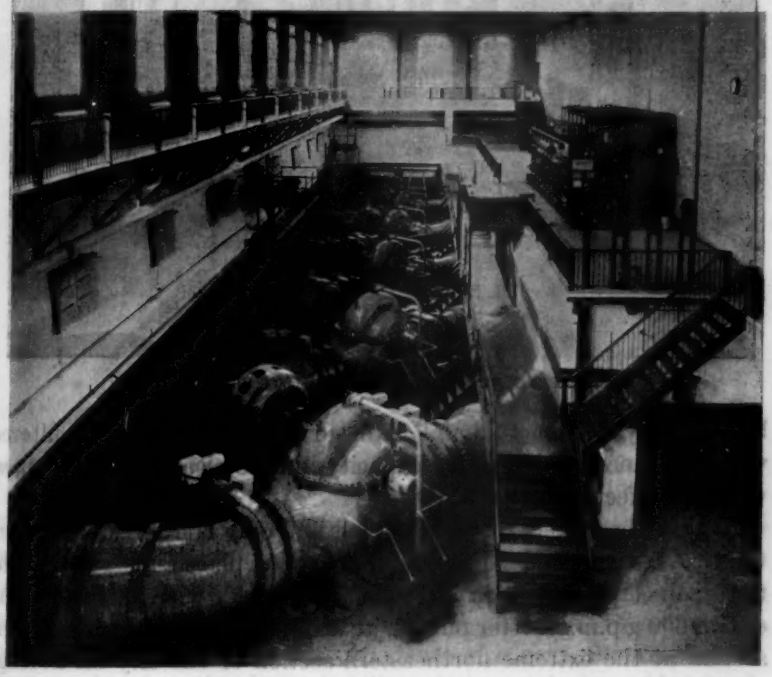
NEW PUMPING STATION AND FILTRATION PLANT

To remove the hazard of having all the pumps confined to one building, and to meet the challenge of the ever increasing demand, the Col. Francis G. Ward Pumping Station, which increased the pumping capacity to 330,000,000 gallons, was added to the system in 1915. The population was then 470,000, the maximum daily pumpage of that year was 207,000,000 gallons and the maximum daily per capita was 428 gallons.

In 1916 Buffalo adopted a new charter and replaced a large unwieldy legislative body with the, then, very popular commission form of government. The Water Department was placed in the control of men of vision and experience who inaugurated many delayed reforms and major improvements. A serious effort was made to improve the efficiency of the system that lacked only that to bring it to a position where it would be comparable to any in this country. The next ten years saw the per capita consumption reduced to a point where, at least, it was not disgraceful. This, and its attending benefits, were conferred on the system by a pitometer waste and leak survey; all employees of the department were included in the New York State pension system; civil service benefits were expanded; rates were increased, and the financial structure improved. Through the favorable vote of a referendum the people gave their approval to the construction of a $4,500,000 filtration plant and it was built. Failing in their efforts to have legislation passed that would compel



COL. FRANCIS G. WARD PUMPING STATION—BUFFALO



LOW LIFT PUMPS—WARD PUMPING STATION

the metering of all domestic supplies, an educational campaign was conducted with the object of impressing on the domestic consumer the merits and advantages of metering. It met with very little, if any, success.

The mineral content of Buffalo's water is such that tuberculation and incrustation are not serious. Deficiency in carrying capacity has been almost entirely due to silting caused by excessive turbidity of the lake during storms. In preparation for the filtration plant 166 miles of pipe were cleaned. It was believed, and it was later

OPERATING FLOOR—BUFFALO FILTRATION PLANT

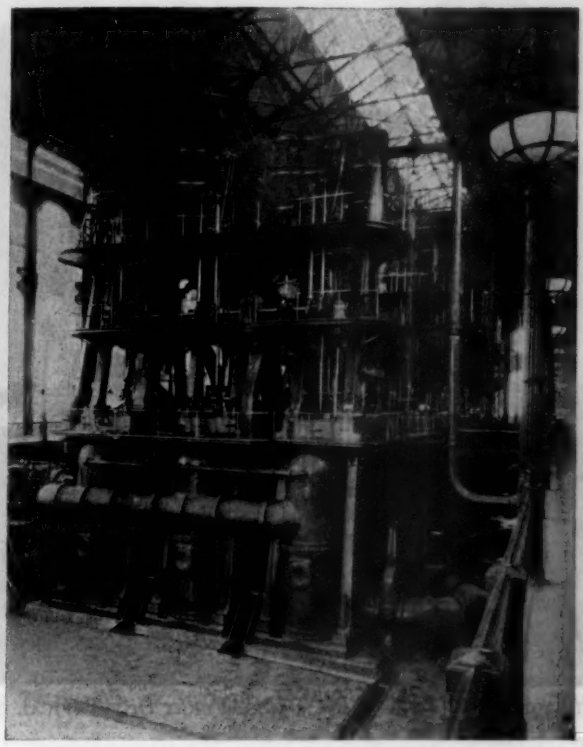
borne out by a pitometer trunk main survey, that distributing filtered water, the increased carrying capacity, due to cleaning of the pipes, would be effective for many years.

In 1927 the system received its first and only booster station when the Grover Cleveland Tower and pumps were placed in service. The tower, an elevated tank of 250,000 gals. capacity with an installation of two 600 g.p.m. booster pumps, guaranteed to a rapidly developing section at the extreme northeastern section of the city an average pressure of 40 lbs. per square inch where previously pressures as low as 15 lbs. per square inch had been common.

OPERATING DIFFICULTIES

For many years an occasional chlorophenol taste to the water had been extremely annoying to the consumer. This objectionable feature was permanently removed in 1928 by the construction and maintenance of phenol recovery plants by the offending industries.

A serious condition confronted Buffalo in 1934 when ice obstructions at the intake, on two occasions, resulted in almost a complete



HIGH SERVICE PUMPS—WARD PUMPING STATION

stoppage of water in the supply to the high pressure service. For 15 years there had been practically no trouble caused by ice at the new intake and in a spirit of optimism, and as a measure of false economy, in 1926, all precautions to prevent the clogging due to ice had been removed benefitting from the experience of a near catastrophe, the present administration has rehabilitated the intake, provided funds for its maintenance and has taken every precaution, including the

installation of a two-way intake to-shore radio communication system, to avert a similar crisis in the future.

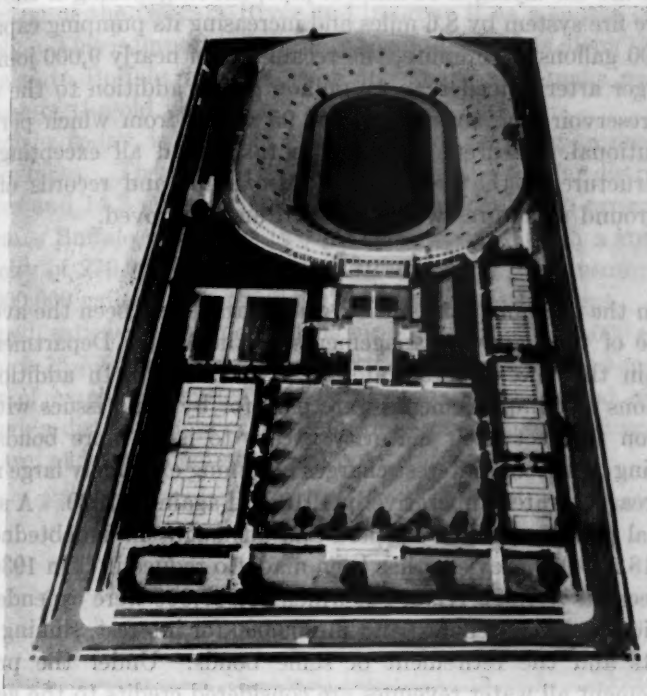
ELEVATED TANKS

There never was a time when the pressure in the reservoir service was considered adequate and due to persistent complaints of insufficient pressure in this area it was decided, in 1936, to place the entire city on the single pressure system. This, due to the comparatively

TWO MILLION GALLON ELEVATED TANK—FERRY ST. TYPICAL OF THREE ERECTED IN 1936

level topography of the city was entirely feasible, but, in consequence of its elevation, involved the abandonment of the forty-two year old reservoir. To replace some of the storage thus eliminated three 2,000,000 gallon tanks were erected at widely divergent points near the extremities of the city and the clear water reservoir, at the filtration plant, was increased from 18 million to 30 million gallons. Due to elimination of the boundary between the two pressure systems, and for probably the first time in its history, all of the valves of the

system were opened. The new arrangement is a distinct improvement in that storage is well distributed and has been made available to the old high pressure service which now covers more than two-thirds of the total area of the city. Distributional balance has been improved, the pumping rate is more nearly uniform, the pressure at the high pressure pumps has been decreased, the installation of additional distributional capacity has been postponed and fire protection



ARCHITECTS SKETCH OF STADIUM ON SITE OF OLD BEST ST. RESERVOIR

has been improved. Normally the tanks will "float on the line" but they are provided with automatic cone valves to prevent overflowal. The elevation of the water in the tanks is recorded at the pumping station by means of telemeters.

To obtain an economical height for the tanks based on existing and future conditions, a pitometer trunk main survey was made which, incidentally, proved that the carrying capacity of the mains is better than normal when the age of the pipe is considered.

RELIEF PROJECTS

During the too many years of the recent depression the Water Department, co-operating with various governmental agencies such as the E. R. B., C. W. A., and P. W. A., acted as the instrument by which unemployment conditions might be relieved. Many improvements that increase the efficiency of the present plant and prepare it to cope with the assured growth of the future were made. Included in these are the laying of 36 miles of pipe, the lengthening of the high pressure fire system by 8.6 miles and increasing its pumping capacity by 9,000 gallons per minute, the recaulking of nearly 9,000 joints of the larger arterial feeders, a 12 million gallon addition to the clear water reservoir, the construction of 95 vaults from which periodic distributional measurements may be taken and all excepting the superstructure of the new tanks. Also maps and records of the underground structures were corrected and improved.

DEPARTMENT FINANCES

From the beginning and until recent years it had been the avowed purpose of the various managements of the Water Department to maintain the lowest water rates in this country. In addition all extensions and improvements were paid for by bond issues with no provision to meet their maturity except to issue more bonds. A mounting deficit and interest charges becoming extremely large made an increase in rates imperative in 1916 and again in 1920. A sound financial policy was then adopted and although the indebtedness is now $18,255,000 provision has been made to reduce it. In 1936 the total receipts were $2,412,000 of which $1,097,000 were expended for operation and maintenance and $1,209,000 for interest, sinking fund deposits and the retirement of some bonds. Under the present arrangement all water revenues are considered credits to the general city fund and water expenses are budgetary charges which must be approved by the governing body.

The present meter rate schedule provides for a graduated rate varying from $1.00 to 40 cents per thousand cubic feet, supplemented by a minimum charge depending upon the size of the meter.

Buffalo's present daily per capita of 194 gallons admittedly high, must not be interpreted as indicating any neglect of the distributional system. It must be remembered that twenty years ago it was 350 gallons, 56 percent higher. Any variation from what is considered normal for other cities must be charged to Buffalo's in-

equitable and antiquated flat rate method of apportioning the cost to the domestic consumer and the belief, long held, that cheap industrial water encourages industrial growth. That policy has met with some success, as Buffalo, now 12th in population, is 8th in manufacturing and first of all cities of over half a million population in volume of manufacturing output per capita.

Buffalo will soon see the completion of a $15,000,000 sewage disposal plant and sewer construction program which will greatly reduce pollution of the Niagara River and improve it as a source of water supply. This is important not only to all settlements along the river but also to Buffalo, in that, some emergency may make necessary the use of the old intake.

Buffalo, today, is a city of 620,000 people, covering an area of 40 square miles. There are 768 miles of pipe in the regular distribution system and 14.2 miles of pipe in the independent high pressure fire system. Buffalo maintains two pumping stations with a combined capacity of 270,000,000 gallons. The average daily consumption is 116,000,000 gallons, and the daily per capita is 194 gallons. The, it is hoped, satisfied consumer, who is supplied through 119,000 services of which 16,730 are metered, is assured of an uninterrupted supply of water of excellent physical, chemical, and bacteriological qualities through a distributional system of ample proportions with pressures that are, at least, adequate at all points of the city.

THE MONTREAL WATERWORKS*

By C. J. Des Baillets

(*Chief Engineer, Montreal Water Board*)

In 1800, a private company, known as "Proprietors of the Montreal Waterworks" was given an exclusive franchise for fifty years. This company obtained water from a pond in the rear of Cote-des-Neiges village, and conveyed it through wooden pipes, laid around the southern slope of the mountain, via Monklands and Cote St. Antoine Road, to two cisterns one of which was placed at the corner of Guy and Dorchester Sts. and the other on Notre Dame St., just west of Dalhousie Square.

The company's troubles began soon after it started operating. The supply of water was uncertain, and the frequent bursting of the wooden pipes finally resulted in the enterprise becoming a failure.

In 1816, the franchise was sold to a new private company which abandoned the gravity system and established a steam pumping plant located at the corner of Water and Friponne Sts., the supply being obtained from the St. Lawrence River. Instead of wooden pipes, 4-inch cast iron pipes were installed, and wooden cisterns were erected on Notre Dame St., east of Bonsecours St. The first cisterns were found to be too weak and in due course were replaced by other wooden cisterns lined with lead. The capacity of the cisterns was 240,000 gallons.

Operating troubles caused the sale of this company to a third private company, which replaced the small pipes with pipes 10 inches in diameter and installed more powerful pumps. In 1843 two pumping engines with a pumping capacity of 93,000 gallons per day were employed, and at this time there were 14 miles of pipes laid in the streets.

MUNICIPAL CONTROL OF THE WATERWORKS

In 1843, the first agitation for a municipally owned waterworks was started, and two years later the city purchased the private company for £50,000. In 1847, the Water Committee suggested that

* Presented before the Canadian Section, April, 1937.

a premium be offered for the best plan to force water from the St. Lawrence River into a reservoir on the mountain. A scheme was presented but was not considered practical and therefore was not acted upon.

In 1849, the city constructed a three-million-gallon reservoir on what is now St. Louis Square, at a height of 130 feet above the St. Lawrence River. At that time there was 19 miles of cast iron pipes and 6 miles of lead pipes in the distribution system.

FIRST AQUEDUCT SCHEME

In 1852, the year of the great fire when much of the waterworks plant was destroyed, Thos. C. Keefer was engaged to prepare a plan whereby the city would obtain an entirely new water supply. The plan he proposed was adopted and was in operation until 1905, when it was materially changed.

The Keefer plan included the construction of an open canal having the entrance on the St. Lawrence River, about 1½ miles above the Lachine Rapids. This canal, or aqueduct, was about 40 feet wide at the water surface and 8 feet deep, and had a length of about 4¾ miles, with a building called the "wheel house" at the lower end. The wheel house contained two hydraulic wheels operating a set of six pumps with a combined capacity of four million gallons a day. From these pumps the water was conveyed through a 24-inch cast iron pipe to a reservoir on the mountain, on the site of the present McTavish Reservoir. The canal was more than sufficient to develop 300 hp. and to raise five million gallons of water a day to a height of 200 feet above the river water level.

Much trouble was experienced during the winter months with ice blocking up the canal and with water backing up in the tail race, and at times the supply of water was not sufficient. The waterworks superintendent made a plea for the purchase of steam engines to prevent water famines, and in 1868 the first steam engine was installed. Other steam engines were added from time to time, but so steady was the increase in population that there was constant fear of a shortage of water.

By 1870, the situation was again critical and expert advice was employed. The scheme finally adopted was to extend the aqueduct and make a new entrance about 3,000 feet above the old location and to enlarge the canal to give an average water section of 100 feet by 14 feet, and thus obtain sufficient power to supply 30 million

gallons of water per day. This work was begun in 1877 and partly completed, but lack of funds and frequent changes in the membership of the city council hampered its completion. Meanwhile more steam pumps were added, thus increasing the cost of pumping.

Thus, at the end of the 19th century, after 100 years of struggle, the Montreal waterworks system was still inadequate both as to quantity and quality of the water furnished.

The water supply situation again became so serious in 1904, that the chief engineer of the city studied a plan for the remodelling of the entire aqueduct system, and in 1905 proposed a plan since known as the "First Enlargement of the Aqueduct."

Briefly stated, this plan included:

(1) the enlargement and deepening of the canal so as to furnish a maximum of 5,000 hp. and a minimum of 2,000 hp. during winter conditions, which minimum was needed to pump 50 million gallons per day;

(2) the construction of a suitable hydraulic power and pumping station;

(3) the enlargement of the tail race;

(4) the construction of a concrete conduit along the side of the aqueduct canal to supply water to the existing steam pumping station while the enlargement of the aqueduct was in progress; and,

(5) the construction of two river intakes, one near shore and the other 1200 feet from shore, to bring water to the shore gate house of the lateral conduit.

A contract for the lateral conduit was awarded in 1907, and in 1910 contracts for the construction of the river intakes were given. Contract No. 1 for the enlargement of the canal was also awarded in 1910.

In November, 1910, about six months after work on Contract No. 1 was started, the city engineer proposed a more ambitious hydraulic power project, known as the "Second Enlargement of the Aqueduct." This project proposed such widening and deepening of the canal as to produce a minimum of 10,000 hp. at all times, 6,000 of which would be available for pumping 100 million gallons of water per day, the remaining 4,000 hp. being for other municipal needs.

This project was adopted, and in the fall of 1912, Contract No. 1 was cancelled. In June 1913, Contract No. 2, for earthwork and concrete structures, was awarded, and work was continued until December 1917, when the contract was cancelled.

FILTER PLANT CONSTRUCTION

The yearly death rate from typhoid fever had steadily increased since 1900, and during the winter at 1909–10 particularly, the city experienced a severe epidemic of the disease. Between October 2nd, 1909 and March 5th, 1910, there were 1,884 cases of typhoid fever resulting in 203 deaths. Following an engineering report on the situation, the city, in November 1910, voted $1,500,000 for the commencement of a filter plant. Contracts for this plant were awarded in 1911, but due to the war and other causes, the plant was not put into service until April 1918.

In 1915, the chief engineer of the city outlined other works needed to complete the project for the second enlargement of the aqueduct. His report advocated:

(1) extension of the guard pier at the entrance of the aqueduct;
(2) the deepening of the approach channel;
(3) the installation of head gates at the entrance of the aqueduct;
(4) the construction of eleven bridges across the aqueduct; and,
(5) the construction of a hydro-electric power and pumping station adjacent to the existing low level steam pumping station.

Following this report, specifications and drawings were prepared and contracts awarded for the LaSalle and Church bridges and some other parts of the works therein mentioned.

Difficulties of all kinds continued to prevent the carrying on of the city's plans for the improvement of its water supply system. The contractor engaged in carrying out the work on Contract No. 2 excavated too close to the lateral conduit, which broke on Christmas Day 1913, and the city was practically without water for about ten days.

This disaster brought to a breaking point the long previous controversy on the part of several organizations as to the merits of the city's plans for waterworks improvements, with the result that several boards of engineers made reports concerning the aqueduct work.

IMPROVEMENTS RECOMMENDED

The last report, dated December 31st, 1919, reviewed all previous reports, and the principal recommendations were the following:

(1) that the aqueduct be completed for water supply purposes;
(2) that a new motor-driven pumping station be constructed and operated on electrical power purchased from the Montreal Light,

Heat & Power Consolidated, and that the equipment in the present steam plant be eventually disposed of;

(3) that the rated capacity of the filtration works be increased to approximately 120 m.g.d.; and,

(4) that additional elevated storage be installed.

Matters relating to the supply, pumping and distribution of water were not the only difficulties with which the city had to contend. Labor troubles within the department had at various times been experienced, but it was not until 1920 that they got beyond control.

About January 1st, 1920, the pump room and boiler room employees at the low level station and other employees of the Water Department went on strike, leaving the department demoralized. Men employed to take the place of strikers were often in sympathy with those on strike and did their best to prevent operation. Members of labor unions throughout the city also gave their support to the strikers in many ways.

Water taps were left running, hydrants were opened and sometimes broken to prevent their being closed, with the result that at times it was impossible to keep any water in the reservoirs on the mountain, or to furnish any water for business or domestic use in some of the higher sections of the city. Risks from fire were greatly increased due to lack of pressure in the water mains throughout the city. It was not until February that these difficulties were sufficiently overcome to obtain anything like normal conditions of service.

THE MONTREAL WATER BOARD CREATED

The problems pertaining to the waterworks had now become so numerous and were of such magnitude that the then existing staff in charge of operation and maintenance of the waterworks were unable also to undertake the study and solution of development problems, and the carrying out of the works necessary for the current and future needs of the city.

The Administration Commission, by resolution dated May 3rd, 1920, thereupon created the Montreal Water Board, consisting of three members who, with a chief engineer and his staff, were entrusted with the work of re-establishing the entire waterworks system on a sound basis for adequate and efficient service.

The year 1920 marked the beginning of a new chapter in the history of the Montreal waterworks, and the principal units of the sys-

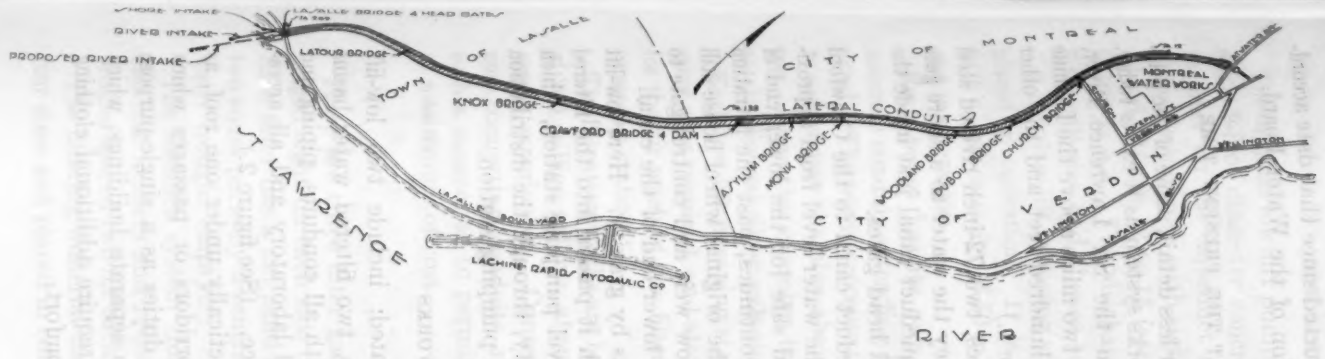


FIG. 1. TOP. MONTREAL AQUEDUCT CONNECTING ST. LAWRENCE RIVER INTAKES WITH VERDUN PUMPING STATION AND PURIFICATION PLANT

FIG. 2. BOTTOM. PLAN OF PRESENT AND PROPOSED INTAKES—ST. LAWRENCE RIVER

tem as it exists today have been constructed since that date according to the plans and under the direction of the Water Board.

THE MONTREAL WATERWORKS AT THE PRESENT TIME

The following will describe, in more or less detail, some of the principal divisions of the Montreal waterworks system as it exists today.

The water supply is obtained from the St. Lawrence River, through two river intakes located about two miles above the Lachine Rapids. One intake is located a few hundred feet and the other about 1200 feet from shore. (See figure 1.)

From each of these submerged intakes, two 72-inch riveted steel pipes, laid in the bed of the river, convey the water to a shore gate house and thence to the head of the aqueduct canal just inside the LaSalle bridge, which houses the Canal head gates.

The water then flows down the aqueduct canal to the Crawford bridge and control dam which lowers the water level from approximately river level to a level considered safe for the lower end of the canal. From this point, the flow continues, past the filtration works intake to Atwater Ave., where the original wheel house still stands. At this site, there is an overflow weir and control gate to maintain the desired water level in the lower end of the canal.

The water reaches the filtration works by gravity. Here low-lift pumps raise it to the filters from which it passes into the filtered water basins, and thence to the low-level pumping station, which pumps the entire water supply of the city, through the distribution system, to the McTavish reservoir and pumping station.

THE FILTRATION WORKS

The filtration works, as now operated, include two low-lift pumping stations, 48 rapid sand filters, two filtered water basins and two wash water tanks, together with all conduits, piping and equipment, chemical and bacteriological laboratory and all accessories for complete and satisfactory service. (See figure 2.)

The entire plant is compact and practically under one roof, as the several units are connected by corridors or passages which enable the operators to carry on their duties as a single-purpose staff, without having to go outdoors to separate buildings, which during cold, stormy winter days would require additional clothing and entail loss of time and physical discomfort.

LOW-LIFT PUMPING STATIONS

The original low-lift pumping station receives its supply through a single 9-foot diameter concrete conduit, which connects the intake chamber on the aqueduct canal with the pumping station. The station is equipped with eight motor driven pumps operating against a head of from 12 to 15 feet. The combined capacity of all pumps is 150 m.g.d. The discharge is carried by conduits through the filter galleries and thence to the filters.

A new low-lift pumping station has recently been constructed and placed in operation. It is arranged for five motor-driven pumps with a unit capacity of 50 m.g.d. Three of these pumps are installed and in operation.

Each pump has its own suction conduit—a 6½ foot reinforced concrete conduit extending to an intake gate house on the aqueduct canal. The pumps receive their supply by gravity and lift the water to a discharge chamber above the suction pipes and within the building. From this chamber the water flows through concrete conduits to the several filter galleries.

Each low-lift pumping station has such electrical and other equipment as is required, and also contains wash water pumps. A blower for the air wash of the filters is also installed in the original low-lift pumping station.

The filtration works are being planned for an ultimate daily output of 300 million gallons, about double the maximum daily output already experienced. Consequently, the low-lift pumping stations and connecting conduits are designed for future requirements in such a manner as to permit of successive increases in plant output at a minimum of cost.

FILTERS

There are three filter galleries with 16 filters to each gallery, arranged eight on each side of central supply and discharge conduits. Each filter has a net sand area of 1,200 square feet, separated into two equal parts by a central gutter into which the 16 concrete wash water troughs empty.

The strainer system (for both water and air wash) consists of cast iron headers and 1¼-inch cast iron laterals, with $\frac{3}{16}$-inch bronze nozzles spaced two for each 6 inch length along the lateral.

The filtering material consists of 15 inches of gravel, graded into four sizes and placed in corresponding layers, and 30 inches of sand,

having an effective size of 0.45 mm. to 0.55 mm. and a uniformity coefficient of about 1.65.

The nominal filter capacity is 3¼ m.g.d. or say 50 m.g.d. per gallery, or 150 m.g.d. for the present plant. Each filter has its own operating table upon which are located the loss of head and rate of flow gauges, and levers for the hydraulically operated water and air valves.

The wash water is obtained from two elevated concrete tanks with an operating capacity of about 100,000 gallons each. The air wash is obtained from a blower in the original pumping station. This blower has a capacity of 5,000 cu. ft. of air per minute against a pressure of 5 lbs. per square inch. It is started or stopped by a button on each operating table.

FILTERED WATER BASIN

There are two filtered water basins built of reinforced concrete. The original filtered water basin, with a capacity of about 5 million gallons, is below the filters and filter galleries. The new filtered water basin, with a capacity of 20 million gallons, is located between the filtration works and the new low-level pumping station; and it is from this basin that the main pumps obtain their supply.

LABORATORY

On the ground floor of the new wash water tank building, which lies between the original and the new low-lift pumping station, is a well equipped laboratory for both chemical and bacteriological work in connection with the proper tests and sanitary control of the public water supply. To this laboratory are daily brought samples of the raw water, samples from individual filters and samples of the combined filtered water output of the plant, both before and after sterilization; also samples taken from the domestic supply in remote parts of the city.

STERILIZATION EQUIPMENT

Located between filtered water basin No. 1, which first receives all water filtered, and filtered water basin No. 2, is the chlorination and sterilization building, which contains the platform scales for the one-ton liquid chlorine drums and the chlorine flow control units. In the west end of filter gallery No. 3 is located a control board,

where the weight of chlorine used is graphically recorded, and upon which are the manual and automatic controls for the chlorine units.

The equipment for the automatic control of chlorine gas has been almost entirely the work of John Harrington, chemist, and A. Kilpatrick, superintendent of the filtration works. After several years of study, they constructed a crude working model which was demonstrated during the convention of the Canadian Section of the American Water Works Association in Montreal in 1925. Working equipment later was constructed under their specifications and supervision, and the apparatus now in service is one of the most interesting features of the waterworks plant.

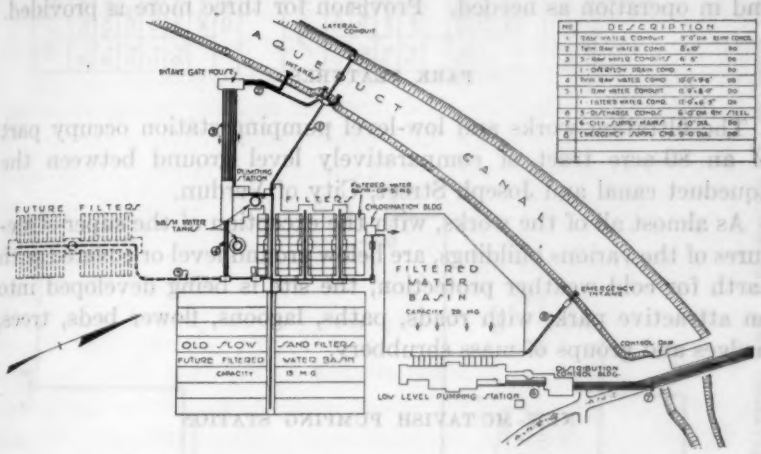


FIG. 3. FLOW DIAGRAM—LOW LEVEL PUMPING STATION AND FILTRATION PLANT

LOW-LEVEL PUMPING STATION

The low-level pumping station is located adjacent to filtered water basin No. 2. The structure includes a central control building, two pump rooms, two electrical buildings and a wing building at each end, one of which contains a machine shop and store rooms.

On the ground floor of the central control building is the local service electrical apparatus; on the second floor is the control room, containing the switchboard and electric operating table, the hydraulic table and Venturi meter registers for the pumping units. This room affords an unrestricted view of both pump rooms. On the third floor are the offices of the Montreal Water Board.

Each pump room is arranged for six motor driven centrifugal pumps, having a unit capacity of 30 to 35 m.g.d. against a head of 250 feet. All suction and discharge piping is located in the basement. The electrical building contains on two floors all high tension and low tension equipment required for pump operation.

The discharge from the pumping units is controlled by Larner-Johnson valves, and then flows through three 72-inch steel headers to an adjacent control building, where the three headers are split into six 48-inch force mains to carry the water supply through the city's distribution system to the McTavish reservoir located on the mountain. At present, nine 30 m.g.d. pumping units are installed and in operation as needed. Provision for three more is provided.

PARK FEATURES

The filtration works and low-level pumping station occupy part of an 80-acre tract of comparatively level ground between the aqueduct canal and Joseph Street, City of Verdun.

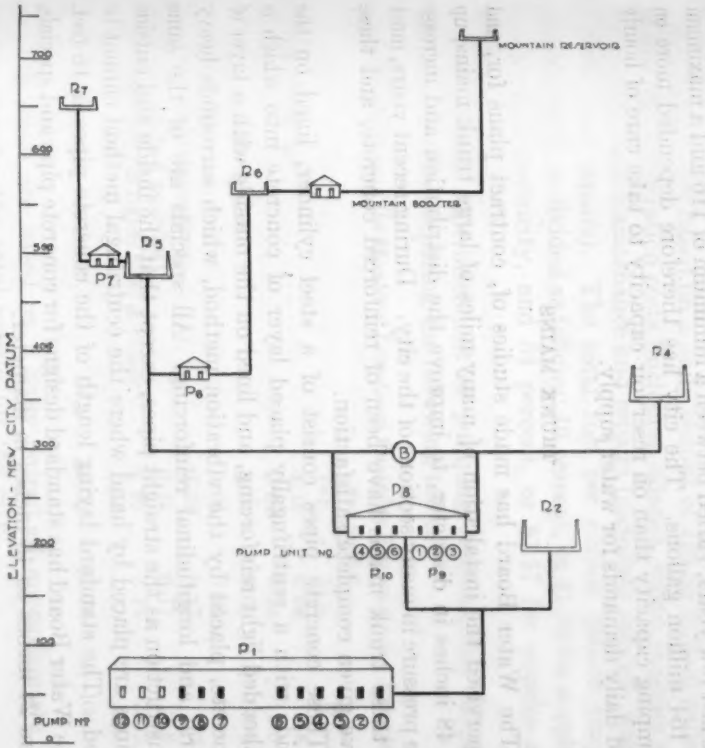
As almost all of the works, with the exception of the super-structures of the various buildings, are below ground level or covered with earth for cold weather protection, the site is being developed into an attractive park, with roads, paths, lagoons, flower beds, trees, hedges and groups of mass shrubbery.

NEW MC TAVISH PUMPING STATION

The new McTavish pumping station, designed by and constructed under the supervision of the Montreal Water Board, is located near the former McTavish station and is adjacent to the McTavish reservoir, from which it takes its supply of water to be pumped to higher districts. The building is of stone and its architectural features are in keeping with the beautiful adjacent structures, such as the Royal Victoria Hospital and the McGill University.

The station includes three 19½ m.g.d. pumping units to supply Outremont reservoir, and three 15 m.g.d. units to supply Cotes-des-Neiges reservoir, together with all necessary mechanical and electrical equipment for proper operation.

There are four other stations for the pumpage of water to higher districts on the mountain, but they are small in capacity.



RESERVOIR		APPROX. CAP. M.G.	ELEVATIONS NEW CITY DATUM		DISTRICT SUPPLIED
			BOTTOM	HW. LINE	
R_2	McTAVISH	45.0	205.67	233.09	LOW LEVEL
R_4	OUTREMONT	45.0	354.50	387.47	OUTREMONT
R_5	COTE DES N.	7.5	477.60	499.00	COTE DES N.
R_6	CEDAR	0.2	564.42	574.42	CEDAR
R_7	WESTMOUNT	0.04	650.50	660.50	WESTMOUNT
	MOUNTAIN	0.2	727.28	737.28	MOUNTAIN
	TOTAL	95.94			

STATION		APPR. PRESSURE LBS. PER SQ. IN.		PUMPS		APPR. CAP M.G.D.	
		STATIC	NORMAL	℄ ELEV.	Nº	EACH	TOTAL
P_1	LOW LEVEL	7.8	9.2	51.58	9	30.0	270
P_8	McTAVISH			216.02			
P_9	UNITS - 1-2-3	7.4	9.0	216.02	3	19.5	58.5
P_{10}	UNITS - 4-5-6	12.2	12.4	216.02	3	15.0	45.0
P_6	CEDAR	8.5	9.5	377.28	2	0.4	0.8
P_7	COTE DES N.	7.3	* 8.8	491.50	5	VAR	3.9
	MOUNTAIN	7.5	8.0	563.66	2	0.15	0.3
					TOTAL		378.5

NOTE

RE: P_7 PUMPS ARE FREQUENTLY OPERATED FOR DIRECT PRESSURE SUPPLY OF 90# TO 108# IN WHICH CASE WESTMOUNT RESERVOIR AUTOMATICALLY SHUTS OFF AT 90#

FIG. 4. PUMPING STATIONS AND RESERVOIRS, ELEVATION AND CAPACITIES

RESERVOIRS

The city has six reservoirs, but only two, the McTavish reservoir and the Outremont reservoir, need special mention, as the combined capacity of the other four reservoirs is less than eight million gallons. (Fig. 4.)

The McTavish reservoir, with high water line about 180 feet above the center line of the pumps in the low-level pumping station, is a concrete lined, open reservoir, with a capacity of about 43 million gallons. This reservoir floats in the line and controls the head against which the low-level pumps operate.

The Outremont reservoir is also an open reservoir, with high water line about 150 feet above high water level in the McTavish reservoir, and has a capacity of about 50 million gallons.

It is thus seen that the total reservoir capacity is less than 100 million gallons, whereas the daily consumption of water has, during the last few years, varied between a minimum of 116 and a maximum of 164 million gallons. The city has therefore depended more on pumping capacity than on reservoir capacity to take care of hourly and daily demands for water supply.

TRUNK MAINS

The Water Board has made studies of, contract plans for, and supervised the installation of many miles of large trunk mains, up to 48 inches in diameter, to improve the distribution and increase the pressure in many sections of the city. During recent years, most of these trunk mains have been of reinforced concrete, and these have given complete satisfaction.

These concrete pipes consist of a steel cylinder, lined on the inside with a centrifugally placed layer of concrete into which is embedded light reinforcing, and lined on the outside with a layer of concrete, placed by the vibration method, which surrounds heavy spiral and longitudinal reinforcing. All specials are of the same construction as the straight pipes, except that the inside and outside linings are placed by hand where the centrifugal method cannot be used. The standard laying length of the concrete pipes is 16 feet. The Water Board has standard designs for concrete pipe and specials, from 24 inches to 48 inches in diameter.

OPERATION COSTS

A few figures covering the costs of operation may be of interest. A. Kilpatrick, superintendent of the filtration works, supplies the costs given in the following table:

Cost of Operation of the Montreal Filtration Works for the Year 1936

	Cost per M.G.		Percent of total
	Imp.	U. S.	
Supervision	0.10	0.08	4.6
Pumping Station	0.27	0.22	12.4
Filters	0.39	0.33	18.0
Laboratory	0.12	0.10	5.6
Sterilization	0.21	0.18	9.7
Buildings	0.19	0.16	8.7
Grounds	0.14	0.12	6.5
Electricity for light, heat & power	0.75	0.62	34.5
Total	$2.17	$1.81	100

These costs are based on a daily output of 128.85 million gallons, and comprise operation costs (including salaries, wages, supplies and electricity), and maintenance and repairs (including salaries, wages, supplies and repairs). The total cost per million gallons (imp.), namely $2.17, is divided as follows: 46 percent, or $1.00 for supplies, repairs and electricity, and 54 percent, or $1.17 for salaries and wages.

A. C. Read, superintendent of pumping stations, has supplied the data used in preparing the following tables:

Cost of Operation of the Montreal Low-Level Pumping Station for the Year 1936

	Cost per M.G.		Percent of total
	Imp.	U. S.	
Supervision	0.10	0.08	1.8
Wages	0.64	0.54	11.3
Equipment repairs	0.04	0.03	0.8
Supplies	0.06	0.05	1.1
General Maintenance	0.21	0.17	4.0
Grounds and aqueduct	0.16	0.13	2.8
Electricity for light, heat & power	4.49	3.74	78.2
Total	$5.70	$4.74	100

These costs are based on a daily output of approximately 130 million gallons, the total supply for the city.

Cost of Operation of the McTavish Pumping Station, Montreal, for the Year 1936

	Cost per M.G.		Percent of total
	Imp.	U. S.	
Supervision	0.11	0.09	1.7
Wages	0.68	0.57	10.4
Equipment repairs	0.01	0.01	0.1
Supplies	0.02	0.01	0.3
Building and grounds	0.20	0.17	3.0
Electricity for light, heat & power	5.57	4.64	84.5
Total	$6.59	$5.49	100

These costs are based on a daily output of approximately 56 million gallons, which represents the re-pumpage of about 43 percent of the daily pumpage of the low-level pumping station.

SUMMARY

Starting in 1920, when the Montreal water supply system was in serious difficulty with inadequate supply, purification, pumpage, distribution and storage, the Water Board laid out a progressive program of works to be done in the order of their greatest need.

Pumping stations have been constructed which provide ample capacity for the present and provision for future extension.

The filtration works have been enlarged to three times their former capacity.

Large distribution mains have been laid throughout the city to improve both supply and pressure.

The McTavish reservoir has been lined with concrete and its capacity somewhat increased.

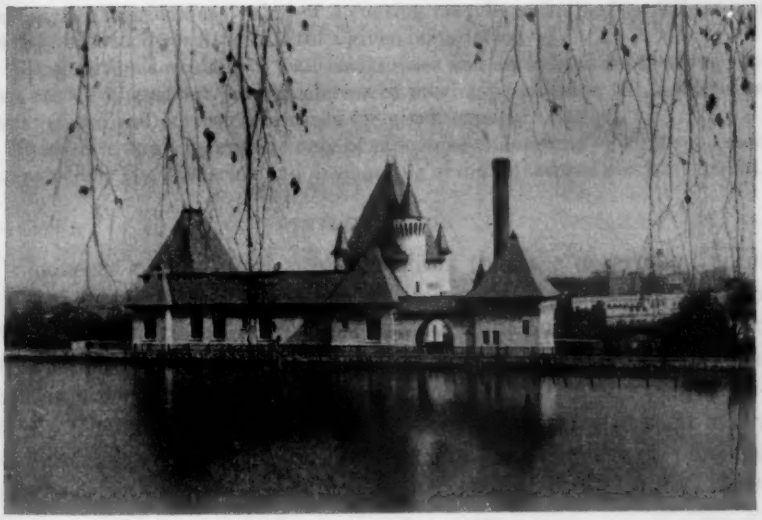
In 1927, the city of Montreal purchased the privately owned Montreal Water and Power Co., and thus acquired its distribution system and the Outremont reservoir. The pumping station and filtration plant owned by the company were abandoned and the site of these works was sold.

Today the Montreal waterworks system is well established, according to the Water Board planning, and capable of giving reliable and efficient service. The tables of operating costs, presented previously, show that the pumping stations and filtration works are supplying water at very low costs.

However, the program is not yet completed, and among the works still to be done are the following:

New River Intakes. Plans and specifications have been prepared

McTavish Pumping Station—Front View
French Renaissance Architecture in a Water Plant



McTavish Pumping Station—Rear View, Reservoir in Foreground

and tenders received for new river intakes, located at such distance from shore as to obtain the St. Lawrence water and not, as at present, the Ottawa River and highly polluted shore waters. (See figure 2.)

Cote-des-Neiges Reservoir and Pumping Station. Contracts are ready for replacing an entirely unsatisfactory existing reservoir and pumping station by new works of greater capacity.

Filtration Works Extension. The future capacity of the low-level pumping station and filtration works has been established at 300 million gallons per day. To bring the filter capacity up to the present capacity of the low-level pumping station, preliminary plans have been made for a new filter gallery.

Distribution Mains. Additional large distribution mains are needed and will be contracted for as soon as funds are available.

Storage Reservoirs. The storage capacity of the existing reservoirs is too small to provide an adequate supply in case of emergency, and also to permit of more uniform pumping and consequently greater economy. Studies have been made, and additional storage reservoirs are on the list of works to be done.

A METHOD OF DETERMINING WALL THICKNESS OF STEEL PIPE FOR UNDERGROUND SERVICE*

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Abstract: Corrosive action of soils on rolled and cast ferrous materials has been observed by the National Bureau of Standards and others over a considerable period of time. Certain fundamental factors affecting corrosion and certain trends in corrosion rates have been perceived. Methods of soil testing involving principal factors of corrosion have been developed and associated with longer time observations. By assigning observed approximate values to factors in a corrosion equation and by distinguishing soil types by methods developed, wall thickness of ferrous metal pipe to remain unpunctured for a selected time of exposure may be approximated with fair degree of accuracy for given conditions of installation hazards and pipe line design.

Behavior underground of various common protective pipe coatings has been observed by The American Gas Association, The American Petroleum Institute, The National Bureau of Standards and others. Combining the observed data on bare metal specimens with the observed data on coating behavior, the approximate value of a coating may be appraised in dollars and cents or in extended service life for a given installation.

Using methods explained, wall thicknesses and associated protective coatings are developed for several classes of steel pipe suitable for installation under stated soil corrosion hazards for given exposure period.

These data apply to outside only of pipe lines undergoing natural corrosion not caused by the gathering and discharging of manufactured electric current.

INTRODUCTION

Engineers generally are prone to think that the determination of wall thickness of steel pipe lines and selection of protective coatings to resist underground corrosion is a matter of pure judgment based on experience and is not subject to ordinary methods of calculation such as are commonly used with other types of engineering structures. The complexity of the processes of corrosion with their many involved factors, together with the confusing results of personal experience, is to a great extent responsible for this attitude. How-

* Presented at the Buffalo Convention, June, 1937.

ever, the serious study which has been given underground corrosion in recent years has developed facts showing that certain soils are highly corrosive and others are not; that certain means may be used to distinguish corrosive soils from non-corrosive soils; that some sort of relationship exists in a given soil between behavior of small specimens and behavior of operating pipe lines, that a certain corrosion-time relationship exists for a given soil and that it is possible with an interesting degree of exactness to fit mathematical expressions to the data.

The purpose here is to present engineering data on soil corrosion and to apply them in the orderly manner of designing procedure familiar to all engineers. An empirical formula for wall thickness is given together with values for variables and constants. Since the accuracy of any empirical equation depends upon accuracy of the values used in calculating, the selecting of these values must be done with care.

It may be argued that the ultimate inaccuracy of such a method is sufficient justification to discard it. The answer to this would seem to lie in the fact that it is the purpose of design in any engineering structure to obtain a desirable degree of safety and service at a minimum cost. Practically all engineering design formulas are to some extent mathematical approximations and contain factors whose values are determined by judgment and practice. In spite of these things, such design formulas are invaluable and are accepted almost without question by the engineering profession. The accuracy of the corrosion equation has been checked against operating pipe lines with results sufficiently close to justify its general use at least until some better means of design can be devised.

It should be noted here that the subject matter of this paper refers to outside corrosion of pipe lines in soil and not to internal corrosion due to water. Internal corrosion is rarely an important factor in puncturing commonly used thicknesses of steel pipe even while assuming serious proportions in its effect on carrying capacity.

SOIL CORROSION FACTORS

General. It is not within the scope of this paper to discuss causes or processes of soil corrosion. Only measurement or gage of principal factors bearing upon design will be considered. Scientific discussions of corrosion may be found in the works of many authors. The remarks here will be confined to useful results of investigations.

All discussions and calculations herein refer to pit depth measurements as distinguished from total loss of weight due to corrosion and have reference to data on rolled ferrous plate materials as distinguished from cast ferrous materials.

Action of Corrosion. The electro-chemical theory of corrosion is now generally accepted since its hypothesis best explains the natural phenomena encountered. Corrosion of metals in soils is accompanied by a flow of electric current which for some reason or other gathers on the pipe and then discharges into the soil. Where the current enters the metal no harm results. Where it leaves the metal pitting develops. The path of current may be long or short.

For purposes of discussion in this paper a distinction will be made between (1) corrosion of metal by soil, and (2) "self" corrosion of metal due to impurities within that metal. The second factor will not be considered except to state that values of constants developed are based on average combined behavior of rolled ferrous materials exposed in National Bureau of Standards twelve-year tests.

The most obvious measurable factors affecting soil corrosion are: (1) soluble soil salts; (2) total acidity; (3) electrical conductivity; (4) soil structure as it affects internal drainage and aeration; and (5) moisture content.

Investigations. The overall effect of corrosion factors has been measured in terms of depth of deepest pits in uncoated ferrous materials in the soil corrosion investigations of the National Bureau of Standards made on about 5500 bare pipe specimens exposed from two to twelve years in forty-seven test sites distributed over the United States. Test sites were chosen as being typical of soil types known to cover large areas in which operating pipe lines were or might be placed.

Before burial specimens were cleaned and weighed. After removal from test sites they were shipped to the Bureau of Standards, cleaned, weighed and loss of weight and deepest pits determined. Special care was taken when cleaning to avoid removing any appreciable amount of metallic iron. The depth of the five deepest pits on each specimen was measured with micrometer gage. Data on pit depths and loss of weight have been published in condensed form in various Bureau of Standards reports. The depth of deepest pits on rolled or wrought ferrous specimens form the basic data from which were derived the various relations given in this paper.

Important conclusions bearing upon interpretation of corrosion data are:

1. Soils differ greatly in corrosivity.
2. Rates of corrosion change with the period of exposure and ordinarily decrease with time.
3. Depth of deepest pits on a corroded area bears some relation to total area exposed.
4. Under apparently uniform conditions, rates of corrosion of two specimens of the same material may differ widely. (However, Bureau data show that if conditions at a test site are uniform, 12 specimens will yield an average having a standard error not greater than 10 per cent.)

Correlating Laboratory Tests. The Bureau of Standards has shown it possible to correlate with fair accuracy the results of 14-day laboratory tests on a soil sample taken from a given test site with results shown by pipe specimens buried 12 years in that soil. This work formed an intermediate step to a shorter time (24 hrs.) cell-type laboratory test which gives for an unknown soil a value of what may be termed its "native" corrosivity index. This index is used in the corrosion or pit depth-time equation.[1]

PIT DEPTH-TIME RELATIONSHIP FOR BUREAU SPECIMENS

The Bureau of Standards investigation of depth of deepest pits on rolled specimens indicates that for a particular soil the pit depth-time relationship can be expressed by an exponential equation. Equation is that of a parabola:

$$P = kT^n \qquad \text{Eq. 1}$$

where P = depth of deepest pit in mils (1 mil = 0.001 inch)
T = time in years
n = a constant for a given soil
k = pit depth in mils on unit area for unit time for the given soil. (Termed in this paper "native" corrosivity index.)

While above equation expresses pit depth-time relationship satisfactorily, it is probable that there are other equations to which the data may be fitted equally well. One is the hyperbolic corrosion rate equation devised by Gordon Scott.[2]

Using area of a 3″ pipe specimen as a basis, the Bureau of Standards calculated values of n and k for T = 5.3 years for specimens in each of forty-seven test sites.[3] By means of an area relationship factor,

or area-safety factor, described later, the approximate depth of the deepest pit on an operating pipe line may be calculated from data on Bureau specimens.

In the pit depth-time equation, the exponent n is constant for a given soil but varies for different soils. For convenience in discussion, soils may be classified according to drainage or aeration:

Group I. Aeration good. Characterized by no mottling anywhere in soil profile and very low water table. *Average n = 0.20.*
Includes:
1. Coarse sands or sandy loams such as Bureau test soils 6, 12, 24, 31 and 36.
2. Light, textured silt loams such as soils 18, 22, 32 and 35.
3. Porous loams or clay loams thoroughly oxidized to great depths such as soils 3 and 11.

Group II. Aeration fair. Characterized by slight mottling in lower part of profile and low water table. Soils would be considered well drained in an agricultural sense in that no artificial drainage necessary for crop raising. *Average n = 0.35.*
Includes:
1. Sandy loams.
2. Silt loams.

Group III. Aeration poor. Characterized by heavy texture and mottling close to surface with water table at about pipe depth. Usually occupy flat areas and would require artificial drainage for crop raising. *Average n = 0.48.*
Includes:
1. Clay loams.
2. Clays.

Group IV. Aeration very poor. Characterized by water table at surface (soils 29, 33 and 43), or by extreme impermeability because of contained colloidal material (soil 28). *Average n = 0.68; maximum n = 0.92.*

It must be recognized that if economy is to be practiced in pipe line installations, pipe wall thickness should be determined in accordance with requirements and should be neither too thick nor too thin. If there are several types of soils with various degrees of corrosivity

existing along a proposed pipe line, evidently the greatest corrosive action will occur in soil having greatest corrosivity. The value of a soil survey with its consequent identification of soils lies in providing means of determining the specific thickness required to resist puncture in each of the various soils.

PIT DEPTH-AREA RELATION

Whenever a ferrous metal surface is exposed to soil, a large number of pits develops which vary in depth. If exposure conditions do not vary, it may be expected from laws of chance that the larger the exposed area the greater the chance of finding a deeper pit. Having measurements of pit depths developed on small specimens, problem is that of determining probable depth of deeper pits on operating pipe lines.

This involves a study of probabilities quite similar to that of determining the probable size of the largest flood apt to occur in a given stream within a given number of years when the size of an average yearly flood is known over a relatively short period. In the case of floods, one engineering formula (Fullers) indicates that the maximum to be expected for a particular stream in a fifty-year period is 2.36 times the average as found for that stream over a period of five or ten years. For a hundred-year period the multiplier is 2.60 and for a thousand-year period 3.40. These figures are quoted to show the relatively small increase of the multiplier for a great increase in time and to show also that the laws of chance are involved occasionally in important engineering work.

Statistically many natural and economic data show a tendency to group about an average value. The average is obtained from both the great and the small and the degree of variation between individual values becomes a measure by which to determine the chances of finding an exceedingly large individual value as the total number of individual values increases.

If individual measurements of deepest pits are normally distributed and if one uses the standard deviation of such measurements shown by Bureau of Standards data, chances are that 99.7 percent of the values will be less than 2.35 times the average.

It is known that neither rain storms nor pit depths are distributed normally but the agreement between safety factors for fifty year floods and largest expected pit depths on the above assumption is interesting in an engineering sense.

What is known concerning relation between pit depth and area has been obtained by observing the manner in which the average value of depth of deepest pits increases as associated areas are increased in size. Studying approximately 8,800 pit depth measurements on various sizes and combinations of the Bureau specimens as well as similar data on seven actual operating pipe lines, Scott[4]

TABLE 1

Values of area-safety factor F and of 1/F for various diameters of pipe

PIPE DIAMETER, INCHES	F	1/F	PIPE DIAMETER, INCHES	F	1/F
A[1]	1.00	1.00	12	2.37	.42
B[2]	1.15	.87	14	2.43	.41
1	1.63	.61	16	2.48	.40
2	1.81	.55	18	2.52	.40
3	1.93	.52	20	2.56	.39
4	2.01	.50	22	2.60	.38
6	2.14	.47	24	2.63	.38
8	2.23	.45	30	2.72	.37
10	2.30	.43	36	2.80	.36

A[1]—area of 0.40 sq. ft.
B[2]—area of 1.00 sq. ft.

reached the conclusion that over a limited range of area, the relation between pit depth and area could be expressed by an exponential equation.†

Values obtained from the exponential equation are essentially area-safety factors. It is customary in engineering to use safety factors in design. Table 1 shows the values of these area-safety

† Scott's equation is:

$$P = bA^a \qquad \text{Eq. 2}$$

where P = depth of deepest pit on area A
a = a constant, depending upon conditions of exposure
b = a constant, the mean of depth of deepest pits on unit area.

For Bureau specimens in forty-seven test sites, value of coefficient a lies between 0.082 and 0.194 in all instances except two, both of which are relatively non-corrosive soils. Average of forty-seven values is 0.149 and value a = 0.15 is used for general calculation in this paper.

To make recorded pit depth measurements on Bureau specimens directly usable for pipe line wall thickness calculations, Eq. 2 may be transformed by substituting in it two associated values of A and P, as A_s, P_s and A_L, P_L

factors (designated as F) for various diameters of pipe and are proposed multiplying factors to be used to go from pit depths published for Bureau of Standards specimens (area = 0.4 sq. ft.) to pipe lengths in operating pipe lines.

Obviously there are other ways of applying the pit depth-area relation in design. It is not within the scope of this paper to discuss these ways except to say that the above method represents a considered opinion, that when used in conjunction with other factors in the corrosion equation results are interestingly accurate. As a tool of design it may well be used until a better one is fashioned.

EFFECT OF PROTECTIVE COATINGS

General. The protective effect of coatings has been investigated by the Bureau of Standards, The American Gas Association, The American Petroleum Institute and others. No general, clean-cut method of dealing with the coating problem seems to have been proposed. Individual experiences have for most part indicated procedure to be followed in given instances.

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where subscripts s refer to Bureau specimens and subscripts L refer to operating pipe lines. Dividing and simplifying:

$$\frac{P_L}{P_s} = \left(\frac{A_L}{A_s}\right)^{0.15} \qquad \text{Eq. 3}$$

Scott (4) states that it is reasonable to extend Eq. 3 on the basis of 20-foot lengths of pipe. Extending it to include much larger areas begins introducing an error on the side of safety which seems to greatly exaggerate requirements as gleaned from actual experience. However, since 40-foot lengths of steel pipe are commonly used for water lines it is logical to relate pit depths to 40-foot lengths.

Bureau pit depth data are recorded as deepest pits on specimen areas of 0.4 sq. ft. so that in Eq. 3 $A_s = 0.4$. Substituting for A_L the area of a 40-foot pipe length, making d = outside diameter of pipe in inches and making exponent a = 0.15, Eq. 3 becomes:

$$\frac{P_L}{P_s} = \left(\frac{40\pi d}{12 \times 0.4}\right)^{0.15} = (26.2d)^{0.15} \qquad \text{Eq. 4}$$

or

$$\frac{P_L}{P_s} = F \qquad \text{Eq. 5}$$

where $F = (26.2d)^{0.15}$

Problem of the designing engineer is to decide: (1) when coatings are necessary; (2) where they shall be placed; (3) of what they shall be made; (4) how they shall be applied; (5) what probable additional life is added by coating; and, (6) what probable additional life would result if metal of equal cost were added to pipe wall instead of coating.

Schematic methods of dealing with these phases of the problem are presented based upon such data as are available. Accuracy of methods and calculations can be developed by check against small specimen performance and pipe line performance.

Coating Investigations. The determination of actual effectiveness of coatings in preventing corrosion on pipe lines has been hampered by the fact that many soils are not seriously corrosive to metal or destructive of coating. Since probably ninety percent of pipe line footage in the United States lies in such soils, any and all coatings in many cases have shown an excellent service record This excellent record was not due to inherent good qualites in the coating but rather to the fact that the soil was not destructive of either pipe or coating.

Some of the sites selected by the American Gas Association and the American Petroleum Institute for coating tests represented soils of a nature that required a good coating to protect metal. Data from these sites therefore provide quite accurate information on coating performance.

Some conclusions appearing in A.G.A. Proceedings:

1. No coating in either the A.G.A. or A.P.I. tests has entirely prevented corrosion in all test sites, but most coatings have reduced pitting.
2. Thin paints, cold applications, and majority of single hot-application bituminous materials unshielded give unsatisfactory protection. (External wrapping material is termed a shield; fibrous material applied as an integral part of the coating is termed reinforcing.)
3. Shielding and reinforcing yield an economic advantage disproportionate to the added cost.
4. Lower economic limit of coating thickness including shielding or reinforcing is believed to be about $\frac{1}{16}$ inch.
5. Coal tar base materials are more stable and moisture proof than asphalt but have a greater tendency to flow when warm and to crack when cold. Good coatings can be designed

using either coal tar or asphalt, choice between the materials depending upon relative cost.

6. Machine applied coatings are more effective than hand applied coatings.

Use of Data. Data from A.G.A. tests cover three specimens each of forty-two kinds of coatings on two-foot lengths of 2″ pipe in each of fourteen test sites. Practically every site is an extreme soil in one property or another. Specimens were buried in 1929, first set was removed in 1930, second in 1932, third in 1935 after about five and one-half years exposure. One set still remains underground in 1937. Data of examinations appear in A.G.A. Proceedings for years 1930, 1931, 1933 and 1936.

The A.P.I. tests give data on nineteen kinds of coatings on operating pipe lines at fifteen test sites also data on forty-six kinds of coatings applied to two-foot lengths of 3″ pipe at some sites. One purpose of short coated sections was to determine relation, if any, between coating performance on small specimens and on operating pipe lines. Conclusion was reached[5] that service conditions are more severe on operating lines. Latest available data covers specimens exposed about three and one-half years. Observed results appear in A.P.I. Production Bulletins 208 (1931), 210 (1932), 214 (1934).

Both A.G.A. and A.P.I. tests included bare uncoated specimens at each site to act as gages of soil action on unprotected metal. Pit depths on these specimens were measured and recorded for each exposure period.

Since many of the test coatings have failed due to soil stress or deterioration during the course of exposure, it is reasonable to assume that the measure of effectiveness of these coatings in preventing pitting has now been had and that this effect may be measured in terms of the difference between the depth of pit on the bare pipe and the depth of pit on the coated pipe making some allowance for relative areas involved.

Except in case of heavy clay soils and mucks, where holidays or breaks in coating frequently concentrate corrosive action at the point of break, there is apparently no justification for assuming that pits deepen more rapidly after the coating has failed than they would on bare pipe from the time of break on into the future. In other words, it may be logically assumed that for a given exposure period the difference in dimension between the depth of the deepest pit on the coated pipe and the depth of the deepest pit on the uncoated pipe is

a measure of the effectiveness of the coating in terms of bare metal. This difference measured on small specimens in mils may be termed C—the "corrosion index" of a coating.

When determining the corrosion index in this manner, it is necessary to identify service conditions (since the effectiveness of a given coating becomes less as the service condition becomes more severe) and to associate it with time and area exposed.

It has been noted generally that the pit depths developing under broken down coatings on an operating pipe line are greater than those developing under the same conditions with the same coatings on a smaller test specimen. This condition might be expected when the area relationship existing for pit depth measurements between smaller areas and larger areas is considered. For want of a better measure for this area difference in pit depth, it may be assumed for design purposes that the corrosion index of a coating as determined from observations on small specimens will be, when applied to operating pipe lines, inversely as the area safety factor F used in pit depth calculations.

Using the data in this manner, it becomes possible with the aid of the pit depth-time relationship to evaluate a given coating in terms of bare metal, to determine the relative cost of coating and bare metal for a given soil condition and to determine approximately the postponement time in years of first puncture when the coating is used with a given wall thickness of pipe. To apply this method, severity of service condition must be taken into account for particular coating under consideration.

Values of Coating Corrosion Index. It is not within the scope of this paper to discuss findings of coating investigations relative to various individual coatings tested. Published data may be observed by those interested. Certain general observations may be made, however, relative to types of protective coatings for use in the four soil groups classified in accordance with aeration and drainage.

From investigations conducted it appears possible to design some type of coating which will prevent pitting for at least five years in one or more of the four soil groups. Naturally a coating lasting five years in soils of Group III would probably last longer than five years in soils of Group II and less in soils of Group IV. The corrosion index of such a coating lasting five years may therefore be determined from pit depth-time Eq. 1 using k and n for given soil and T = 5. This result should be modified for relative area before

applying to operating pipe line. The modified index expressed in mils may then be used to determine probable additional time to first puncture if coating is added to given bare wall thickness; or to determine thickness of metal to be deducted and replaced by coating to obtain a coated and uncoated pipe with identical time to first puncture; or index (mils of metal thickness) may be evaluated in dollars and cents to compare relative economy of using coating or additional metal to achieve same result where such choice is expedient.

If experience with specimens or pipe lines indicates life of a given coating before breakdown to be greater or less than five years under given conditions, the same process of evaluation may be followed using proper area relation and all constants corresponding to observed time.

Types of Coating. In soil Group I indications are that coating is probably unnecessary but analysis shows that if a good coating is applied its effect is comparatively great. Cold applied cut-backs and hot bituminous dips are indicated.

In soil Group II nothing less than a shielded hot enamel coating should be used if protection is chosen, but relative cost of additional metal thickness in lieu of coating to achieve same result should be investigated.

In soil Groups III and IV only heavy reinforced coatings can be used.

Cathodic Protection. No consideration of methods of protecting metal pipe lines underground is complete without mention of the successful and ever-growing method of cathodic protection. This name is taken from the nature of process which consists of making the pipe line a continuous electrical conductor negative to galvanic currents in soil through which it passes. The result is economically achieved by impressing sufficient direct current voltage on the ground outside pipe to prevent natural galvanic currents escaping from pipe wall to soil. If all such escape is prevented the experience in oil and gas industries indicates no corrosion will occur.

Ways and means of applying direct current to soil, designing current generating equipment, arranging complete circuits between generator, soil and pipe line are discussed by many authors. It need only be mentioned here that to economically cathodically protect any given pipe line, it should be electrically continuous and coated with enamel of low electrical conductance shielded against soil stress by suitable non-moisture absorbing wrapping. If cathodic protec-

tion is used, thin wall coated pipe renders indefinitely long service. The fact that cathodic protection is successful indicates that currently held electro-chemical theory of corrosion is basically sound.

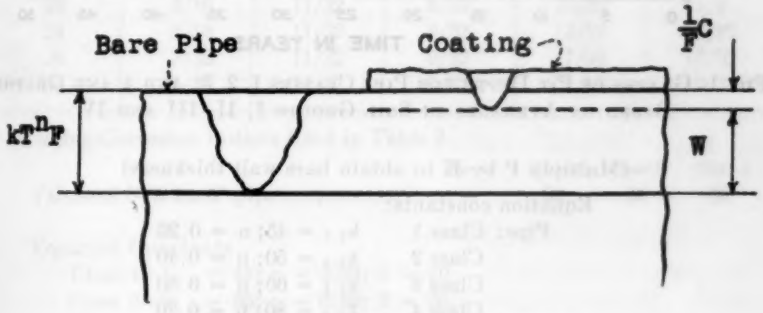
DETAILED CALCULATIONS OF PIPE WALL THICKNESS

General Wall Thickness Equation. Combining mathematical expressions for pit depth-time relationship, area safety factor and modified coating corrosion index gives general equation for pipe wall thickness for a given condition and time of exposure.

General equation including factors discussed may be written thus:

$$W = kT^nF - \frac{1}{F}C \qquad \text{Eq. 6}$$

where W = wall thickness (mils) bare pipe for exposure period equal to time T
k = average maximum pit depth (mils) on 0.4 sq. ft. at one year
T = time of exposure in years
n = constant for given soil
F = area-safety factor
C = coating corrosion index (mils) (C = O for bare pipe)



GENERAL WALL THICKNESS EQUATION

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T = time of exposure in years
n = constant for given soil
F = area-safety factor
C = coating corrosion index (mils) (C = 0 for bare pipe)

The foregoing expression is general but must be modified somewhat in order that tabulated values may be conveniently used.

Working Wall Thickness Equation. The Bureau of Standards has calculated values of k for 0.4 square foot area of specimens corresponding to T equals 5.3 years. When these recorded values of k are used a modification of the general equation must be made by inserting for T^n the term $(T/5.3)^n$.

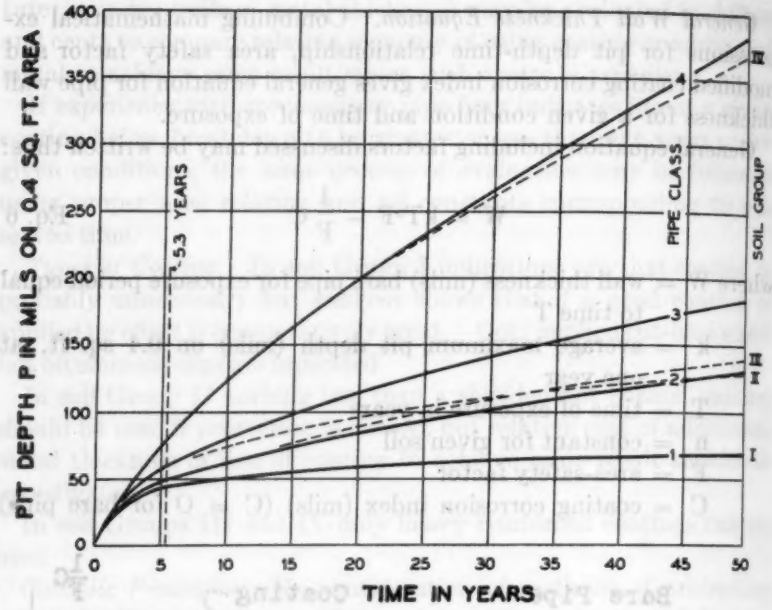

FIG. 1. GRAPHS OF PIT DEPTH FOR PIPE CLASSES 1, 2, 3, AND 4 AND GRAPHS BASED ON AVERAGES IN SOIL GROUPS I, II, III AND IV

(Multiply P by K to obtain bare wall thickness)

Equation constants:

Pipe:	Class 1	$k_{5.3} = 45$; n = 0.20
	Class 2	$k_{5.3} = 50$; n = 0.40
	Class 3	$k_{5.3} = 60$; n = 0.50
	Class 4	$k_{5.3} = 80$; n = 0.70
Soils:	Group I	$k_{5.3} = 45$; n = 0.20
	Group II	$k_{5.3} = 60$; n = 0.35
	Group III	$k_{5.3} = 45$; n = 0.48
	Group IV	$k_{5.3} = 80$; n = 0.68

The working equation then becomes:

$$W = k_{5.3}\left(\frac{T}{5.3}\right)^{n}F - \frac{1}{F}C \qquad \text{Eq. 7}$$

The first step in procedure of evaluating a particular case is to select and test soil samples along given right-of-way using laboratory cell test to determine native corrosivity factor k for 5.3 years and 0.4 sq. ft. area.

TABLE 2

Wall thickness in inches of four classes of steel pipe

DIAMETER, INCHES	CLASS 1	CLASS 2		CLASS 3	CLASS 4
	Uncoated	Uncoated	Coated	Coated	Coated
	T = 50	T = 50	T = 50	T = 50	T = 25
6	11/64	9/32	7/32	11/32	7/16
8	11/64	9/32	7/32	11/32	7/16
10	11/64	9/32	7/32	3/8	15/32
12	11/64	5/16	1/4	3/8	15/32
14	3/16	5/16	1/4	3/8	1/2
16	3/16	5/16	1/4	13/32	1/2
18	3/16	5/16	1/4	13/32	1/2
20	3/16	5/16	1/4	13/32	1/2
22	3/16	11/32	9/32	13/32	1/2
24	3/16	11/32	9/32	13/32	17/32
30	7/32	11/32	9/32	7/16	17/32
36	7/32	11/32	9/32	7/16	17/32

Coating Corrosion Indices Used in Table 2.

	Class 1	*Class 2*	*Class 3*	*Class 4*
Values of C/K for 6″ pipe	—	54	65	86

Equation Constants:

Class 1—$k_{5.3}$ = 45; n = 0.20; T = 50
Class 2—$k_{5.3}$ = 50; n = 0.40; T = 50
Class 3—$k_{5.3}$ = 60; n = 0.50; T = 50
Class 4—$k_{5.3}$ = 80; n = 0.70; T = 25

The second step is to determine field limits (within reason) of soils identified by cell tests.

The third step is to determine value of coefficient n from aeration or drainage condition of each soil on the right-of-way according to its grouping in this respect—Soil Group I, II, III, or IV.

The fourth step is the selection of type of coating and coating corrosion index on five-year or other basis or on actual pipe line performance basis considering native corrosivity of soil and value of coefficient n which measures aeration and moisture conditions.

Classes of Steel Pipe. The more general method of selecting pipe wall thickness is to devise a series of steel pipe classes having different thicknesses designed to fit soils of different corrosiveness, and then, to choose a suitable class for given installation condition. In this method wall thickness of a given class of pipe is determined using Eq. 7 with arbitrary values of k and n the selection of which is based upon the corrosion data obtained from Bureau of Standards observations and with values of coating corrosion index judged on performance basis. The idea, of course, is to provide a pipe wall whose thickness is equal to or greater than the maximum indicated pit depth at a given time for soils in the soil class for which it is suited.

Such a series of classes of pipe with corresponding wall thickness equations is shown graphically in Fig. 1 superimposed upon corresponding graphs of the four soil groups when average values of k and n are used for each soil group.

Table 2 gives computed wall thicknesses using area-safety factor F and coating indices shown.

If pipe wall thickness is selected on this basis, the cell test is relied upon only to indicate that native corrosivity index of unknown soil is such as to place it in one of four classes after field observation has fixed the value of the coefficient n. This method of determination would eliminate some calculation, but is general and therefore probably not as valuable as direct computation for a given installation.

CONCLUSIONS

The Bureau of Standards twelve year underground corrosion test is practically completed. Many data have been observed and correlated. It seems logical that engineers designing pipe lines should now take cognizance of and make use of these data both as to behavior of bare metal and as to performance of coating.

The adoption of standard methods of observation and calculation will improve future knowledge. One method of calculation based on present available information and in fair agreement with common practice is presented. Consistent use of some such method should, with continued check on performance, eventually lead to scientific design of pipe lines and remove it from the field of pure guess work.

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AIR CONDITIONING AS A PROBLEM OF WATER DISTRIBUTION AND DISPOSAL*

By Loran D. Gayton

(City Engineer, Chicago, Illinois)

For many years the city dweller has appreciated the tremendous handicap placed upon him by the unnatural conditions under which he must work and live, and has attempted to correct these conditions in many and various ways. There have been very many back to nature movements, and the migration of peoples from residential sections close to the centers of many of our large cities to the suburbs has been so great that it has created so-called blighted areas. These areas are giving considerable concern to those interested in urban planning and development, and much thought is being given to possible methods for their rehabilitation.

In connection with the efforts being made to improve living and working conditions in urban areas, there is at the present time a wide-spread interest in so-called "air conditioning." I should like to call attention to the fact that this term is being greatly misused and abused. In the past it was considered sufficient to heat the air in the winter and to circulate the air in the summer, whereas, at the present time, attempts are being made to clean, heat, and add moisture to the air in the winter and to clean, cool, and reduce the moisture content during the summer period. The engineering professions, especially those engaged in refrigeration, and in heating and ventilating, have been concerned with this matter of air-conditioning for a considerable time, but it is only during the past few years that the waterworks engineer has awakened to the fact that he is vitally concerned.

Air-conditioning is presenting many varied and difficult problems to the various branches of the engineering profession. Nevertheless, the industry, that is the designing, manufacture and the installation of the equipment is growing at a most remarkable rate. In the matter of the smaller installations, such as are required for small out-

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lying business houses and residences, the problem is primarily one of lowering the manufacturing cost, but in the central business sections of our large metropolitan cities, the major problem is one of adequate water supply and sewers. This is the problem that is now engaging the attention of the waterworks engineer, and in general it is safe to say that in the congested business centers of our cities this matter of complete air-conditioning presents one of the greatest and one of the most complicated problems ever confronted.

The installation of air-conditioning equipment is bringing about a tremendous increase in the demand for water from our municipal supply systems, especially in our larger cities where block after block is built up solid with skyscraper structures. It falls upon the waterworks engineer to meet this demand by supplying water in sufficient quantities, and at whatever location desired. In many instances this demand is making additions necessary to available sources of supply, as well as pumping equipment and distribution mains. Even under ordinary conditions, the waterworks engineer must look from five to twenty-five years into the future, and must design, plan and build to meet the requirements that his studies indicate. The air-conditioning problem is making his work more difficult as far as future planning is concerned.

Chicago is probably typical as far as our larger cities are concerned as regards the water demand in connection with air-conditioning, and this paper has been prepared with the feeling that a description of the methods used in the City of Chicago, in attempting to estimate the future demand for air-conditioning water will be somewhat helpful to waterworks engineers in other cities. The air-conditioning problem in our smaller cities will not greatly differ from the problem in our larger cities. In fact, the problem in the smaller city may in some instances be more complicated, due to more limited sources of water supply.

It should be kept in mind that we are considering only the central business district of Chicago, or the so-called loop area, bounded on the north and west by the Chicago river and on the south by 12th Street, or Roosevelt Road.

According to figures supplied by the Commonwealth Edison Company there were on September 1, 1936, in this area 398 air-conditioning installations, with a total refrigerating capacity of 11,865 tons. If we assume a figure of two gallons of water per minute per ton of refrigeration these 398 installations require water at a

rate of 23,730 gallons per minute, or a rate of approximately 34,000,000 gallons of water per day. (This figure has been checked by actual tests on existing installations.)

In order to impress upon you the great increase in the demand for water in the loop area during the past seven years, I should like to call your attention to three tests made in the district; one in May, 1929, one in July, 1936, and one in September, 1936.

A survey made from May 9th to 15th 1929 showed a peak rate of flow into this area of 52,000,000 gallons per day. Since this survey in 1929 the normal requirement for water in this section has been reduced by the reduction to a minimum by elimination of underground street leakage, and by the razing of many buildings. Therefore, under ordinary conditions the normal demand for water in the loop area should be less in 1936 than it was in 1929. But the following test, made in 1936, shows that the demand has increased, and in this connection it should be kept in mind that since the test in 1929 many installations of air-conditioning equipment have been made in the loop area, and no doubt these installations explain the results of the following test.

Flow measurements were made on July 26, 1936, in hot, dry weather, on the feeder mains supplying the area bounded on the north and west by the Chicago river and on the south by Roosevelt road. The observations were made during the hours of maximum demand (noon to 2 P.M.) a rate of 65,000,000 gallons per day was recorded, which is a higher rate than ever before observed in this section of the city.

A third test was made on September 28, 1936 after a large rainfall and after extremely high temperatures had abated. This test was made during the hours of maximum demand, and showed a rate of flow into the loop area of 39,000,000 gallons per day. A reduction of 26,000,000 gallons per day when compared to the test made in July, 1936.

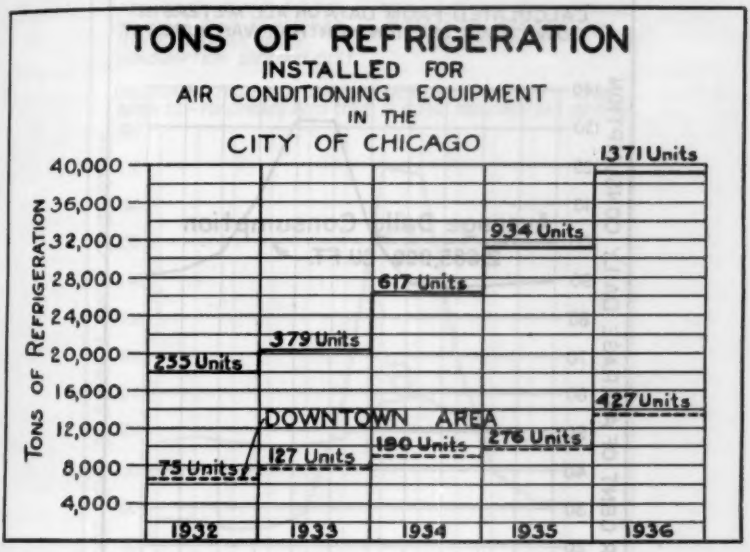
This test is a pretty good check on the estimate of the amount of water required by the 11,865 tons of air conditioning equipment now installed in the loop. It was stated before that if this equipment was operating at maximum capacity, it would require a rate of approximately 34,000,000 gallons of water per day. It may have been that during the test of July 26, 1936 the installed air-conditioning equipment was not operating at full capacity.

The number of persons within the central business district varies

according to the hour, the season, the weather, and to business and other conditions. Counts made on the number of persons entering and leaving the loop by all means of transportation indicate that the greatest number of people there at one time occurs about one-thirty in the afternoon.

These counts corrected for the slightly greater area under consideration, and for permanent residents, furnish an estimate of approximately 400,000 persons within the central district at the peak of an ordinary working day.

If there was air-conditioned space in the Central district for every-one of the 400,000 odd persons we might say that this district was



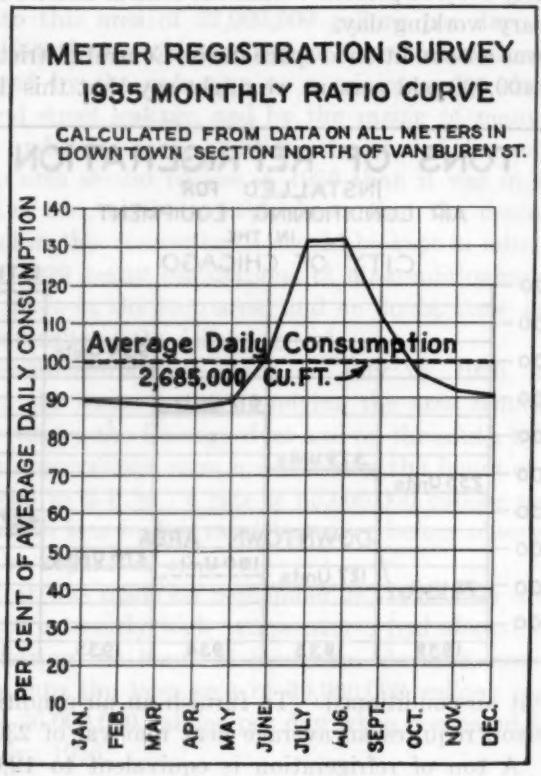
100 per cent air-conditioned. To furnish an air-conditioned space for one person requires an average heat removal of 2300 B.T.U.'s per hour. A ton of refrigeration is equivalent to 12,000 B.T.U. per hour. Therefore, 5.2 persons may be accommodated with air conditioned space by each ton of refrigeration.

The equipment now installed in the Central business district is therefore capable of furnishing refrigerated space to 64,000 persons, or, in other words, the area is a little over 16 percent air-conditioned.

Chart 1 indicates the number and the tonnage of air-conditioning refrigeration equipment installed in the downtown area of Chicago from 1932 to 1936 inclusive.

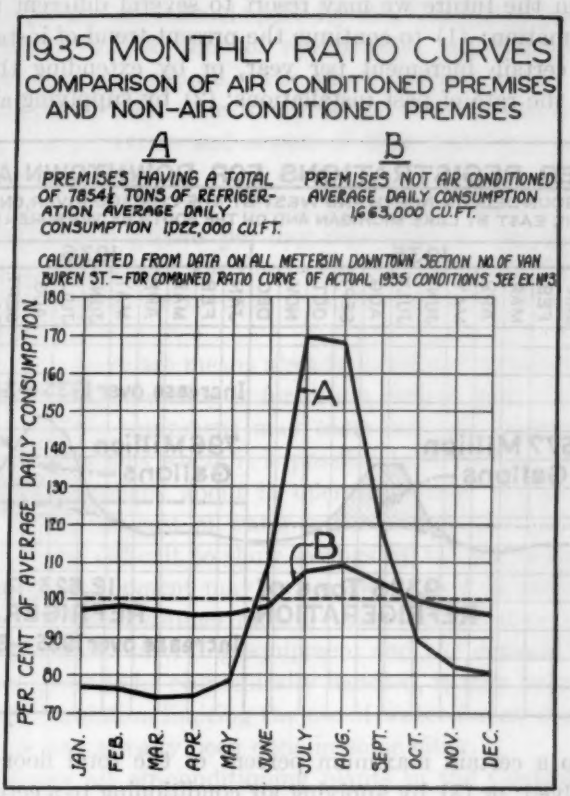
Chart 2, shows the total meter registration in the loop area by months, from January to December, inclusive, 1935. This chart indicates that during July and August, when the air-conditioning equipment is most in use, the demand for water rises to 130 percent of the average for the year.

Chart 3 shows the registration of meters in the loop area by months, from January to December, inclusive, 1935. Curve "A"



shows the registration of meters connected to premises with air-conditioning equipment. This curve indicates that during July and August the demand for water by premises using air-conditioning equipment rises to approximately 170 percent of the yearly average. Curve "B" shows the registration of meters connected to premises without air-conditioning equipment. This curve indicates that during July and August the demand for water by these premises rises to only 110 percent of the yearly average.

Chart 4 shows the consumption of water in the loop area by months for the years 1935 and 1936. This chart indicates that the installed refrigeration equipment in connection with air-conditioning in the loop area was 35.5 percent greater in 1936 than it was in 1935. This chart also indicates that the demand for water in the loop area was 38 percent greater in 1936 than in 1935. This chart



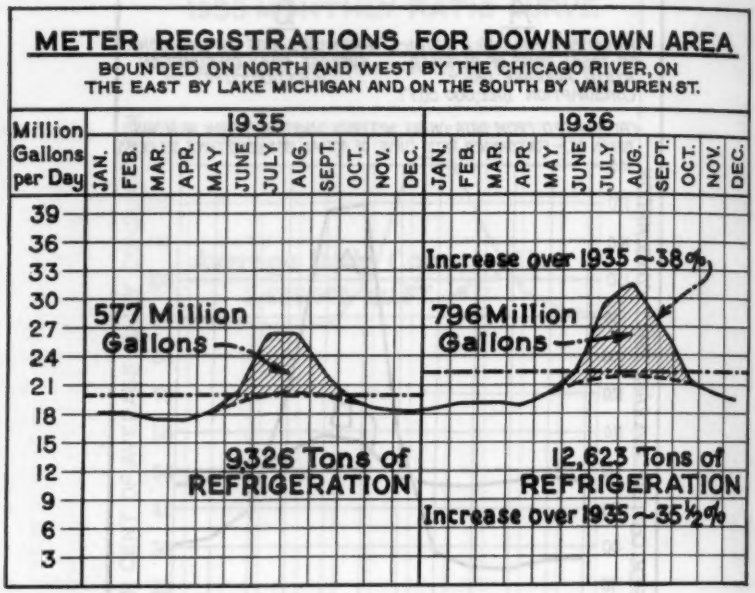
clearly indicates the rapid increase in the installation of air-conditioning equipment in the business center of the City of Chicago.

So much for the present demand for water. Now let us consider the probabilities of the future.

Any method of predicting the future of air-conditioning and its demand for water is more or less unsatisfactory. We know that the demand is gaining headway, and indications are that the progress accelerates for a number of years.

The saturation point of demand is also difficult, if not impossible to predict. Certain classes of users are expected to compete between themselves, until that particular business cannot succeed without air-conditioning. Other classes of business may never require air-conditioning to meet competition.

In an attempt to determine the water demand for air-conditioning purposes in the future we may resort to several different methods of approximation: (1) to continue the present trend of installations, adding a certain increment per year, or by extending the curve shown by the rate of past installations; (2) by supplying air-condi-


METER REGISTRATIONS FOR DOWNTOWN AREA
BOUNDED ON NORTH AND WEST BY THE CHICAGO RIVER, ON THE EAST BY LAKE MICHIGAN AND ON THE SOUTH BY VAN BUREN ST.
Million Gallons per Day
1935
1936
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
39 36 33 30 27 24 21 18 15 12 9 6 3
577 Million Gallons
796 Million Gallons
Increase over 1935 ~38%
9326 Tons of REFRIGERATION
12,623 Tons of REFRIGERATION
Increase over 1935 ~35½%

tioning to a certain maximum percent of the total floor space or area involved; or (3) by applying air conditioning to a certain maximum percent of the number of people involved.

We have used the last method and checked the results within reason by the other two.

We have assumed that within twenty years there will be an air conditioned space for every person normally in the district, or that the district will be 100 percent air conditioned at that time. This does not mean that every building will be air-conditioned but that some may be fully conditioned, others partly conditioned, and still

others not conditioned at all, but that the total of the equipment installed will be sufficient to provide conditioned air for every person.

We have already shown that approximately 400,000 persons are at the present time in the central business district during mid-day and with a normal increase in the population of Chicago this number should reach 530,000 persons in the next twenty years.

To provide air conditioned space for this number of people would require about 102,000 tons of refrigeration and demand 204,600 gallons of water per minute. The water demand for air conditioning equipment at that time would be 295,000,000 gallons per day, requiring pumps, mains and sewers of that additional capacity to furnish water service.

Pumping equipment and piping to supply water at a rate of nearly 300,000,000 gallons per day represents a very large investment and operating cost, and due to the few hours in the year during which it is needed, the revenue from this source will be comparatively small.

Fortunately there are means already developed to conserve water by cooling it and returning it for re-use rather than wasting it to the sewers. This equipment may come into use through its own merits in installations where it is possible to show that by its use a saving can be brought about in operating costs. In the city of Chicago, where the cost of water is the lowest of any city in the world it may be difficult to show savings by the use of such equipment and this equipment may be somewhat slow in gaining a foothold here. If the consumer fails to take the initiative in the installation of water conserving equipment and the demand for water becomes too great to be economically handled, it may become necessary to pass legislation limiting the use of water for air-conditioning purposes, as has already been done in some cities.

If eventually all air-conditioning plants in the Central business district should be equipped with water conserving devices the total amount of water required would probably be about 5 percent of the amount necessary without these devices.

If all air-conditioning plants were designed to conserve the water supply, then in 20 years, when the central business district is 100 percent air-conditioned, the water demand for this purpose would be only about 15,000,000 gallons per day, or less than half of the present demand occasioned by air-conditioning plants now in operation which do not conserve the water supply.

AVAILABLE WATER SUPPLY

The foregoing indicates that at the present time the air-conditioning equipment in the loop area requires a maximum rate of approximately 34,000,000 gallons of water per day in addition to the normal requirements of the territory, and the test of July, 1936 indicates that the peak load requirements of the loop area, including the normal demands plus the air conditioning demands, is at a rate of approximately 65,000,000 gallons per day.

The foregoing study also indicates that in twenty years the loop area may require for air conditioning purposes, 295,000,000 gallons of water per day above the normal requirements.

Now let us study the present available water supply in this territory as compared to the present and future demand.

The loop area is supplied jointly from three pumping stations, The Chicago Ave. Station located at Chicago Avenue and Michigan Avenue; the 14th Street Pumping Station, located at 14th Street and Indiana Avenue and the New Cermak Pumping Station located on Harrison Street just east of Halsted.

From the Chicago Avenue Pumping Station, two feeder mains, one 36 inches and one 24 inches extend into the loop crossing under the main branch of the Chicago River in tunnels at Michigan Avenue, and at LaSalle Street. A 24-inch main also crosses the river and into the loop at LaSalle Street in a tunnel belonging to the Telephone Company, and this main works in parallel with the 36-inch main at this same crossing.

These mains from Chicago Avenue have a combined capacity available to the loop area of 40,000,000 gallons per day at ordinary velocities (five feet).

From the 14th Street Pumping Station, two feeder mains enter the loop area, one 48-inch and one 24-inch. These two feeder mains have a combined capacity of 55,000,000 gallons per day.

From the Cermak Pumping Station, two feeders enter the loop area, crossing under the south branch of the Chicago River in tunnels, one 48-inch main in Polk Street, and one 36-inch main in Harrison St. These two feeder mains have a combined capacity of 65,000,000 gallons per day.

The combined total of these six feeder mains from three separate pumping stations, amounts to 160,000,000 gallons per day at ordinary velocities. In case of a fire or any other emergency, these

feeder mains could be worked to at least a 50 per cent overload, or in other words, if called upon, we could at the present time deliver water at the rate of 240,000,000 gallons per day into the loop area.

The foregoing indicates that there is at the present time available to the loop area, over three and one-half times the peak load demands for water, including the present installations of air conditioning equipment. The indications are that the water now available to the loop area is sufficient to meet all demands for the next ten years.

Now as to the future, plans have been projected to increase the capacity of the grid of the loop area by laying 20-inch, 16-inch, and 12-inch pipes in a number of streets where smaller pipes now serve the present needs. The time of laying these grid mains will be of course determined by future requirements.

THE LOOP SEWER SYSTEM AND AIR CONDITIONING

The first section of this paper indicates that at the present time the air conditioning equipment installed in the Central Business District of Chicago, which equipment uses no water conserving devices, but demands a maximum supply of water for cooling purposes and then wastes this water directly to the sewers when operated at maximum capacity requires a rate of approximately 35,000,000 gallons of water per day. The first part of the paper also indicates that within 20 years this demand of water, providing no water conserving devices are installed, may amount to as much as 295,000,000 gallons of water per day.

The second part of the paper indicates that at the present time there is available to the loop area at least 240,000,000 gallons of water per day, and that this amount of water will take care of all demands in the loop area for at least ten years to come.

In this, the third section of the paper, I shall attempt to picture for you the inability of the sewers in the area to take and dispose of all the waste water from the district under consideration. In order that you may have a proper perspective as regards the sewers in the loop area, I shall give you a little history.

The City Council of Chicago, on January 24, 1910, passed a resolution directing the Board of Local Improvements to investigate fully the needs in the matter of the sewers of the district bounded by the River, the Lake and 12th Street (Roosevelt Road), and to make report thereof to the Council. Much of the material that follows

was taken from that report. The report was made by C. D. Hill, who at that time was Superintendent of the Bureau of Sewers and was considered an authority on sewer design and construction.

"The sewers in the present Central Business District of the City were designed and built between 1855 and 1860 under the direction of Ellis S. Chesbrough, who was then City Engineer. Mr. Chesbrough is regarded by those who know of his work, as being one of the greatest engineers ever developed in this country. In addition to the original Chicago sewer system, he was responsible for the design and construction of the original Two-mile Crib and Tunnel, and the Chicago Avenue Pumping Station, which were completed and put in operation in 1867."

"The sewers in the District under consideration were designed on a liberal scale to provide for the storm water run-off that was to be expected and proved sufficient for the conditions during the following twenty-five years. During that period there were no skyscraper buildings. The pavements of the streets were not impervious. There were considerable areas of private land not roofed or paved, and there was no serious difficulty in draining the streets and the buildings. The conditions of today with large buildings, impervious pavements and private property nearly all covered with either roofs or paved areas, require a capacity much larger than these sewers possess. With the conditions that we will have ultimately, the sewers should have a capacity of about five times the capacity of the present sewers."

Please keep in mind that the foregoing was written in 1911.

The District under consideration is served by main sewers in all of the east and west streets from Randolph Street south. These sewers are three feet in diameter at the outlets where they empty into the south branch of the Chicago River, and are two feet at the summits, which are located between State Street and Wabash Avenue. From the summits, these sewers slope to the east to a main sewer in Michigan Avenue, which is four feet in diameter at the outlet at the main River, and two and one-half feet in diameter at the summit near Congress Street, and thence sloping south to the intercepting sewer at 12th Street.

There are brick sewers two feet in diameter in the north and south streets extending from Randolph Street north to the main River. South of Randolph Street, in the north and south streets, there are tile pipe sewers 12 inches in diameter that empty into the

brick sewers in the east and west streets, having a summit in the middle of each block.

The above describes the loop sewers as originally installed over 75 years ago, and I believe the description is correct as of today, excepting that at present they empty into the inceptors of the Sanitary District.

The report of 1911 in general stated that the sewers were of insufficient size, that they had been badly damaged by the construction of buildings and other structures, that they were not self-cleaning, and that it was practically impossible to keep them clean.

The report made the following recommendation:

"The more this problem is studied, the less possible it seems that we will be able to use any of the present sewers. A system of relief sewers, giving additional outlets to the main sewers, will not be sufficient for the reason that the greatest trouble is from the mall lateral sewers. The entire sewer system should be condemned and replaced with an entirely new system that will be completely up to date and will take care of all future possible developments of the district."

The report also states that the reconstruction of these sewers should have been commenced years ago, but that it was impossible to make any definite plans until the matter of subways in the downtown streets had been decided.

In 1921, the matter of the inadequacy of the sewers in the loop area was again brought to the fore, and plans were made for a system of relief sewers in the area. The estimated cost of these relief sewers was over a million dollars. These plans were never carried out, probably due to the opposition of property owners to paying the cost.

It should be kept in mind that the cost of building sewers is met by spreading an assessment upon all the property affected.

All the foregoing indicates that for over twenty-five years those in authority have recognized the inadequacy of the sewers in the central business district of the city to handle satisfactorily the ordinary storm run-off of the district, and that those in authority have made plans to enlarge the sewers, but for one reason or another have been unable to carry out these plans.

Now with the rapidly increasing demand for water for cooling purposes, in connection with the installation of air conditioning equipment, the inadequacy of these sewers is again brought to

attention. During the past summer, on many clear hot days, the sewers have been flooded and have overflowed into the basements and sub-basements of adjacent property. The matter has become acute, and some solution of the problem must be arrived at at an early date. The past summer has given such conclusive evidence that it can be stated without fear of contradiction, that the present sewers in the Loop area cannot dispose of the waste water from the central business district during the summer season, at the present time, and will not be able to do so in the future unless something is done to reduce the amount of water used for air conditioning purposes.

POSSIBLE SOLUTIONS OF THE PROBLEM

Let us then summarize the facts brought out in the first three sections of this paper. The first section shows that during the past few years there has been a great increase in the demand for water in the Loop area, and that this demand will continue to increase for a number of years to come. The second section shows that the present available water supply in the loop area is sufficient to meet the present demand and the demand for at least the next ten years. The third section indicates that the present sewers in the loop area are inadequate to handle the storm run-off during heavy rains, and are also inadequate to handle the waste from the area during the warm spell of summer when air conditioning equipment is in operation.

Now as to possible solutions of the problem under consideration.

First, as recommended in the report of 1911, the entire sewer system in the loop area could be rebuilt at a cost of many million dollars, or as recommended in 1921, a system of relief sewers could be constructed at a cost between one and two million dollars. The carrying out of either one of these programs would not only entail a very large expenditure, but it would cause a great deal of inconvenience in the streets of the loop carrying heavy traffic, and either program might meet opposition from the business interests in the area affected.

It should be kept in mind that any rebuilding of the "Loop" sewers is tied up with the plans for any future "Loop" subways; also that any expenditure made for enlarging the sewer system to carry away the waste water from air conditioning equipment would be made to meet a peak load demand occurring only during the summer months, or approximately 1000 hours per year.

The second possible solution of the problem is for those requiring air-conditioning equipment, to so design and install that equipment that the amount of water required from the water supply system, shall be reduced to a minimum. The installation of cooling towers, evaporative condensers or other devices that may be developed in the future, would bring this about.

If all the air-conditioning equipment now installed in the central business district were operated at maximum capacity for a period of 1000 hours during the summer, it would use approximately one billion six hundred million gallons of water, and the City would receive an income from this of approximately $111,000.00.

If, on the other hand, all the air-conditioning equipment now installed in the central business district had in use cooling towers or other water conserving devices, the water used would be approximately 5 percent of the above mentioned figure, or approximately 102,000,000 gallons, and the City would receive from the sale of this water, approximately $7,000.00.

As far as the water supply system is concerned, we are in a position to deliver all the water that air-conditioning may require, and we are glad to get the income from the sale of this water.

The problem of the Bureau of Engineering is to supply the demand for water, and we are in a position to meet the maximum demands of the loop area for at least the next ten (10) years; the matter of disposing of the waste water from the loop area is a problem to be met by the Bureau of Sewers, and just how that part of the problem will be met I am not in a position to state. Surely this problem of air conditioning is a major one and far reaching in its effects and can only be solved by the combined planning and coöperation of all those concerned.

WATER REQUIREMENTS OF AIR CONDITIONING MACHINERY*

By E. N. Bowles†

Without the engineers, who are responsible for a steady supply of water, the air conditioning industry would not be in its present favorable situation. We are inclined to assume that we can always get an adequate water supply at suitable pressure, and we generally do get it, and a suitable source of disposal for it. Nevertheless, it is a most important thing to check on any prospective installation.

For air conditioning, the chief water using device is the condensing unit—the purpose of which is to condense a gas or vapor so as to remove its latent heat of vaporization. Most condensing units include a centrifugal or reciprocating compressor, with freon by far the most commonly used refrigerant. The freon machine is selected for most applications, due to its reliable operation, comparative economy in cost and space requirements, its safety and adaptability to local conditions.

Take, for example a 15 h.p. machine, with freon condensing unit. A brief study of its water requirements will indicate the characteristics of such machines in general. It must operate at a given suction gas temperature to furnish desired air conditions. With a discharge pressure of 130 pounds per square inch it will supply 15 tons of refrigeration and require 770 gallons of water per hour, if the water enters the condenser at 60°F. This amount increases to 1060 g.p.h. at 70°, 1640 at 80° and 3820 at 90°. Altering the amount of water used changes the discharge pressure of the hot gas, and this affects the refrigeration capacity and the electrical input of the compressor motor. The water flow is therefore usually adjusted to arrive at the most economical balance of water and power costs, with the refrigeration load as a limiting factor.

Returning to the figure of 1060 g.p.h. with 70° water, this might be increased to 2800 g.p.h. at 110 pounds discharge and there would

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† Air Conditioning Supervisor, Westinghouse Electric and Manufacturing Co. Chicago, Ill.

then be a 10 percent increase in refrigerating capacity and a 6 percent decrease in power input. However, if the cost of water in the community happened to be high, the consumption of 70° water could be cut down as low as 600 g.p.h. with a 5 percent increase in electric cost and a 10 percent drop in refrigerating capacity. With this condition, the water would be discharged to the sewer at about 110°F., which might in some cases violate municipal regulations. In the case of the large consumption of 2800 g.p.h. the condenser friction would be 36 lbs. per square inch pressure drop. This can be overcome by making a simple change in the condenser water header connections, giving more parallel tube flow, but this increases the water used about 25 percent. The pressure drop then becomes less than 9 lbs. in this case.

Where water is scarce or very expensive, condensing is sometimes done by forced air blown through large freon condensing coils, but this means high condensing pressures with resulting high power input and reduced refrigerating capacity. A much more common way of avoiding high water bills is by the use of atmospheric cooling of the water in spray ponds, or towers, or in forced draft towers. The condenser heat is then taken up by evaporating water, and the water is continually recirculated, only make-up water being required. A refinement of this is the evaporative condenser, in which the freon condenser is in effect built right under the spray heads of a forced draft cooling tower.

Water vapor refrigerating machines are sometimes used for larger sized air conditioning installations. When water is cheap and steam available at low cost, the steam jet vacuum plant is often very attractive. Since the motive steam must be condensed, as well as the water vapor which serves as a refrigerant, the water used will be in the range of from 120 to 360 gallons per hour per ton of refrigeration. The Chicago Tribune has a 600 ton steam jet plant, and Sears Roebuck & Company have two 150 ton steam jet plants in St. Louis.

For proper summer dehumidifying, air must be cooled below the dewpoint, or the resulting condition will be very moist and unpleasant. For this reason, well water is seldom successfully used alone for direct cooling of the air unless it has a temperature around 55°F., preferably much lower. Warmer water, such as 60°F. water, is sometimes used in direct air cooling coils in conjunction with supplementary low temperature freon coils. Water coils for air cooling are sometimes used with humidity absorbers, such as the silica gel

system which is promoted by gas utilities. Additional water is required for cooling the silica gel.

Self contained room coolers are not yet an important factor in water use, but may rapidly become so. They have the refrigerating unit built right in the air cooling cabinet. Like the larger freon units, they may be air or water cooled, but for room coolers water piping is sometimes undesirable. Water cooled room coolers average about 30 g.p.h. of 70° water.

The humidifying devices used in winter air conditioning also deserve mention. A space of 10,000 cubic feet needs the addition of about two quarts of water per hour, to maintain a healthy condition in winter in Illinois.

So far, this discussion has only considered apparatus now in general use. The future of air conditioning offers intriguing possibilities. For instance, it is entirely possible to take 50°F. water from a faucet in the home, and use it for heating purposes. To understand this, please remember that a refrigerating machine is essentially a heat pump. In the summer, we can cool air down to 75° even though our condensing water may be 85° in the mains and 105° leaving the condenser. In the winter, perhaps the temperature of the water in the mains is 55° but we can cool it to say 35°, and use the heat removed from it to increase the temperature of condensing water in a closed circuit from say 75° or 85° up to say 115° or 120°. This is known as the reverse refrigeration cycle, and it is in fact a heat pump, with about 5 B.T.U.'s of heat transfer for every B.T.U. of energy represented by electrical input. Nor is this in just the experimental stage. A number of practical installations have been made, and a very notable one is that which both heats and cools the imposing office building of the Southern Sierras Power Company at Riverside, California. They have three 25 horse power refrigerating machines, and use well water as a condensing medium for cooling, and as a source of heat in cool weather. In the heating season, the heat taken from this well water by refrigeration equals the burning of 25,000 cubic feet of gas daily. For their climate, the refrigerating plant required for summer cooling is of adequate capacity to transfer enough heat for the winter heating demand. In the middle west, the heating demand would necessitate a much larger machine than required for cooling, or else the plant put in for cooling could be used, with a supplementary heating system of another type to be thrown on in extreme weather. This means an all-year-around demand for water

main and sewer capacity, or else well water, or a nearby deep river. The control of such a plant is simple and flexible.

Even based on present day air conditioning practice, it is extremely difficult to forecast the future trend of water requirements.

The City of Chicago, not including suburbs, now has air conditioning equipment of an installed capacity of 60,000 h.p. and it is safe to say that in hot weather it requires 60,000 gallons of water per minute. During the depression there was a very healthy increase—in fact all over the country the volume of business was doubled each three years. It is now accelerating much more rapidly.

This great new business is typical of the industries which often help to improve the public welfare, even under adverse conditions, and which open up new opportunities for enterprise. The members of the American Water Works Association can aid this development, by cooperating to ensure that local authorities understand the advantage of adequate water supply and disposal.

WHAT AIR CONDITIONING MEANS TO THE WATER UTILITY*

By L. L. Lewis

(*Vice President and Chief Engineer, Carrier Corporation*)

Almost two years have elapsed since I first had the privilege of addressing a group of your associates.

At your A. W. W. A. meeting in Los Angeles last June, I presented a paper in which data accumulated by the electric utilities were transformed into an index of the water requirements of air conditioning.

A brief review of these data brought up to date will throw some additional light upon this situation as it now exists. Table 1 shows the rate at, and the extent to, which air conditioning has been installed in 19 large cities up to January 1, 1937. It is based on Electric Utility data made available by "Refrigeration News."

The data are given in the form of a population factor and represents that percentage of the city's population for which air conditioning has been installed. Its chief values are that it shows the progress of the demand for water in relation to existing facilities and affords a comparison between cities.

Cincinnati, Houston, Kansas City and New Orleans were installing at a high rate in 1935, but have slowed down considerably. Chicago, Newark, N. J., Pittsburgh, St. Louis and Toledo have substantially increased their respective rates of installation.

The rate of increase predicted for the country in the Los Angeles paper has not been fully realized but the air conditioning industry is still quite optimistic about its future. It should be noted, however, that a 1 percent change for the urban population of the country means the installation of from $75,000,000 to $100,000,000 of air conditioning equipment.

In table 2, certain of the factors of table 1 are converted into units with which you are more familiar—that is, into millions of gallons per day. "Maximum consumption" is the peak rate of pumping and distributing requirements. It will never be sustained for the full

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twenty-four hours, but on a hot day may last at full rate from mid-morning until sundown—when it will fall off quite rapidly.

Also in table 2 is the normal cooling season's requirements for water which must be had from reservoirs, wells or other sources.

TABLE 1

Water factor or percentage of population for which air conditioning has been installed

January 1, 1937

CITY	POPULATION	PRIOR TO 1935	DURING 1935	DURING 1936	TOTAL TO DATE
Baltimore	823,000	3.4	1.5	1.1	6.0
Boston	1,700,000	2.3	0.6	0.6	3.5
Brooklyn, N. Y.	2,560,000	1.5	0.5	0.5	2.5
Chicago, Ill	3,460,000	6.3	0.8	1.2	8.3
Cincinnati	538,000	5.1	2.3	1.6	9.0
Detroit	1,760,000	3.4	1.3	1.2	5.9
Houston	295,000	7.1	4.2	2.8	14.1
Indianapolis	367,000	0.6	1.8	1.2	3.6
Kansas City	405,000	4.6	4.6	2.7	11.9
Louisville	308,000	2.2	1.2	0.9	4.3
Manhattan and Bronx	3,133,000	6.2	1.3	1.4	8.9
Milwaukee	653,000	1.8	0.3	0.5	2.6
Newark	565,000	4.1	0.4	1.3	5.8
New Orleans	459,000	5.5	2.3	1.7	9.5
Philadelphia	1,950,000	4.3	1.2	1.1	6.6
Pittsburgh	832,000	2.5	0.8	1.7	5.0
St. Louis	927,000	3.6	2.9	4.1	10.6
Toledo	292,000	2.5	0.8	5.4	8.7
Sub-total	21,027,000	4.08	1.21	1.35	6.72
Washington, D. C.	487,000	21.2	8.8	10.6	40.5
Totals	21,514,000	4.45	1.38	1.57	7.40

Courtesy Carrier Corporation.

Both of the foregoing demands are based upon a continuance of the 1935 practice of installing water-conserving devices, such as evaporative condensers and cooling towers, for 60 percent of refrigerating capacity. It is my belief that the proportion of such equipment was greater in 1936 than in 1935, but a repetition of the 1935 survey has not been possible.

As stated on previous occasions, such as this, the data in table 2 are of necessity broad averages which must be accepted as the judgment and experience of the author. The local problem will yield accurately to nothing but a survey of local conditions. Washington is an example and its situation would indeed be serious were it not for the proximity of the Potomac river.

But, after all, these figures are of passing interest, for they are merely the present generation of a family which, in the past two years

TABLE 2

Water consumption based on 60 percent application of conserving equipment

CITY	POPULATION	MILLIONS OF GALLONS	
		Maximum day	Normal season
Baltimore	823,000	11.6	330
Boston	1,700,000	14.1	400
Brooklyn, N. Y.	2,560,000	15.5	440
Chicago, Ill.	3,460,000	68.2	1920
Cincinnati	538,000	11.6	330
Detroit	1,760,000	24.5	690
Houston	295,000	9.9	280
Indianapolis	367,000	3.1	90
Kansas City	405,000	11.5	320
Louisville	308,000	3.1	90
Manhattan and Bronx, N. Y.	3,133,000	66.8	1880
Milwaukee	653,000	4.0	110
Newark	565,000	7.9	220
New Orleans	459,000	10.4	290
Philadelphia	1,950,000	30.8	870
Pittsburgh	832,000	10.0	280
St. Louis	927,000	23.5	650.
Toledo	292,000	60.6	1700
Washington, D. C.	487,000	47.0	1320

Courtesy Carrier Corporation.

has not only aroused you but also all others having a pertinent interest or responsibility. For whatever they may have contributed, they may be looked upon as having served their purpose and now should give way to a more exact appraisal of local conditions.

And, so, I venture the opinion that it is time for you to have a better understanding of air conditioning as it is now being vociferously publicized and to a degree exploited.

TYPES OF AIR CONDITIONING

The term "air conditioning" is unfortunately too broad and for a complete understanding, air conditioning must be grouped into at least four classes: (1) winter Air Conditioning, (2) evaporative Cooling, (3) summer Air Conditioning and (4) year-round Air Conditioning.

Winter Air Conditioning. You need have no interest in or concern about winter air conditioning except to distinguish it from the others when you are informed that so many residences have been "Air Conditioned." They probably have been provided with glorified chromium plated (no disrespect) boilers or hot air furnaces and vapor pots.

There is great need for winter air conditioning in the home, for it does away with the destructive effect of excessively dry air upon everything with which it comes in contact—from furniture to the mucous membranes of nose and throat. It should be a part of every heating installation, but its requirements for water are limited to that of several gallons per day at the utmost.

Evaporative Cooling is a type of air conditioning applied mainly to mills and factories, but which is now being advocated by some for limited comfort cooling. It requires only make up water. A very considerable load of evaporative cooling could be connected to your mains without imposing any appreciable demand.

Summer and Year-Round Air Conditioning are different, for both require the removal of heat. That, in turn, much or little water, depending upon the extent to which water conserving equipment is used. Such equipment is well developed and available. It adds, however to the initial investment required for the small plant and therefore leads to the temptation to waste water.

In looking upon summer and year-round conditioning, it is suggested that you divide it into the large plant and the small plant. The large installation will usually include water conserving equipment, because it is recognized by all concerned with it that the demands of air conditioning are approaching the limits of supply and disposal systems, and that without conserving equipment, the service of the plant may be lost when it is needed the most.

In the case of the smaller installation, however, the view may be taken that it requires so little water that no concern need be felt. But in such complacence may lie danger, the avoidance of which may impose upon you the duty of vigilance.

Small plants may be divided into: (1) those using mechanical refrigeration; (2) those using dehydration (Chemical); and (3) those using water directly as a cooling agent.

In plants using mechanical refrigeration, operating costs are materially increased by warm water. Warm water means more electric power to drive the compressor and more water to maintain a suitably low condensing temperature. Normal practice is to provide for the use of about three times as much water if the temperature at which it is available is 80° instead of 70°.

Cold water, while lowering the operating costs of mechanical refrigeration, likewise improves the results which can be obtained with dehydration. (Dehydration is a system in which a chemical having an affinity for water is used to abstract water vapor from the air.) General practice in its application is that of obtaining a lower sensible temperature by offsetting the effect of a high dry bulb temperature with an exceedingly low relative humidity. In other words, the temperature may be permitted to rise to 85 or even 90°, while the relative humidity is held to 35 percent or even lower. High temperatures require less water but there is yet some instability of opinion as to the conditions of temperature and humidity which will prove generally acceptable, and some additional experience must be had before public reaction will be definitely known.

If cold water is available, good results can be obtained with a reasonable quantity of water. If available water, however, is warm, then exceedingly large quantities of it must be consumed.

With the increased popularity of air conditioning has come the reaching for relief from peaks of heat by means of low cost equipment in which water is used directly as a cooling agent, i.e., without refrigeration or dehydration. The results obtained with such equipment are far more favorable in the northern part of the country than in the southern part, due to the relationship between surface or sub-surface water temperature and air temperature. At best they afford relief only from peaks of heat and therefore impose a high peak demand with small usage.

Both the large plant and the small one will impose relatively the same peak demands upon you, but the large plant is more apt to be operated continuously throughout the cooling season than the small one. The installation in the small commercial establishment is more apt than not to be operated continuously, but the small installation in the residence is apt to be pushed to full capacity for perhaps one-

third or one-half of the cooling season and not operated at all during the other part. This probably means that the peak demands upon the pumping station may be felt, as a result of the small installation, long before its drainage upon the supply is noted.

In conclusion, I feel warranted in looking with some satisfaction upon the interest which has been aroused in the problem of the manner and means of supplying water for air conditioning, and upon the increased assurance that you will find means of adequately meeting a reasonable demand, but I consider that you must be alert to the load which is being imposed by the small installation.

WELL WATER CAPACITIES AVAILABLE FOR AIR CONDITIONING*

By Winfred D. Gerber

(*Engineer, State Water Survey, Urbana, Illinois*)

There have been summers just as warm as was the one of 1936 but the idea of producing an artificially cooled air in public and quasi-public buildings (to say nothing of the homes) had not assumed the importance that it now holds in the minds of many. It is likely that last summer's heat helped in a large degree to crystallize the idea into action.

It is very doubtful if air cooling for summer temperatures would have assumed the position it now holds if cooling by means of artificial refrigeration was the only method available.

Cold ground water has a great appeal. The fact that such waters have temperatures as low as 49 degrees in some areas made it an attractive medium for dehumidifying or cooling the air in buildings of many descriptions.

The use of ground water for air conditioning very naturally appealed to the well contractor who saw in it an opportunity to increase his business. The manufacturer of equipment and his sales force very naturally saw an opportunity to create new business.

Unfortunately there is all too often a catch in such hurried developments and the owner or purchaser may as time goes on expect to learn some things he did not anticipate.

Ground water, to be satisfactory as a cooling agent, must be cold, the colder the better. If the temperatures are higher than 55° then the volume of water required is very materially increased.

As previously mentioned, about the coldest water on record in this State is 49°F. but more generally the minimum temperatures are 50° or somewhat above.

It appears from records in the files of the State Water Survey that waters obtained from limestone are as a rule several degrees colder than waters from the sand and gravel deposits of the drift.

*Presented before the Illinois Section, April, 1937.

Why this is so is not known but frequently limestone water will have temperatures of 50° to 53° while in a majority of cases the drift water has a minimum of 54° and from there up to 56° or slightly above. Water obtained from aquifers below 300 to 350 feet in depth are almost sure to be warmer for the reason that temperature increases with depth.

While summer temperatures are no respectors of locations in so far as this state is concerned, the opportunity to develop adequate water supplies for air cooling are definitely limited. For instance, the southern third of the state or that area south of a line through Casey and Carlinville may be regarded as an area of higher temperatures than the northern portion of the state and yet opportunity to develop ground water in sufficient quantities for air conditioning units involving yields of from 150 to 500 gallons per minute do not exist, particularly within the exact and narrowly defined limits of the property whereon the water is to be used.

The few municipalities in this zone that secure their public water supplies from wells frequently find the supply outside of the built up area and not in the business section where the buildings requiring air cooling are usually located.

There is a rather narrow zone, paralleling and a few miles easterly of the Mississippi river wherein water from rock wells is obtained. This zone extends through St. Clair, Monroe, Randolph, Jackson, Union, and Pulaski counties. The production ranges from 35 to 250 gallons per minute, the latter being obtained at Anna. With the possible exception of Steelville and Percy the municipal wells are at favorable locations for water production outside of the business area.

Wells entering alluvial sands and gravels have been developed along the bottom lands of the Ohio and Wabash rivers and usually at locations outside of the business sections.

Except for the chance of finding some alluvial gravels in the bottoms of the Kaskaskia, Big Muddy, or Embarrass river drainage systems the interior counties of this southern area are practically devoid of well water opportunities in excess of 5 to 10 gallons per minute.

A more liberal opportunity for well water supplies is found in the balance of the state or that portion north of the Casey-Carlinville line. Though the opportunity is better in this area, there is a marked difference in the type of aquifer from which such water

can be secured. In the southern portion well waters as a rule are secured from the drift, rock wells being insignificant in number while in the northern portion the majority of wells are of the rock type with only a sprinkling of drift wells.

The upper portion of the state may thus be divided into two zones by a line through the cities of Watseka and Stronghurst. This arrangement divides the state into three zones in which water supplies are or may be obtained from three different sources.

The central portion or zone for convenience called the drift well zone is interesting in that the bulk of the municipal drift wells are in the easterly portion or that part east of the Illinois river. West of the Illinois river there are only four municipal drift well supplies, namely, LaHarpe, Lewistown, Peoria, and Peoria Heights. This means that drift water in all the counties west of the Illinois river is hard to find in suitable quantities for even the smallest communities and any plans to develop sufficient water for air cooling purposes is doomed to failure almost from the start.

East of the river there are many counties where ground water in quantities is hard to secure, namely, Mason, Cass, Morgan, Scott, Greene, Macoupin, Sangamon, Menard, Christian, Shelby, Coles, Cumberland, Clark, Edgar, Douglas, and Vermilion. In the rest of the counties of this zone prolific yields from the drift have been found but not always at as convenient location as was desired. That is to say, the production of the drift is spotty even in the more favorably provided counties.

In the northern zone or that area north of the Watseka-Stronghurst line opportunities are more favorable for well water supplies. Drift waters are found in relative abundance in the upper valley of the Illinois and Fox rivers and in DeKalb, Lee, and Bureau counties. Here again, however, the drift sheet is not continuous and study should be given to the water possibilities before investments are made.

In this northern zone rock wells predominate. The temperature of the water from the deep lying sandstones usually exceeds 60°F.

Limestone water is obtained from the fractures in the rock. For water to enter these fractures there must be sufficient cover of a more or less porous type that will permit percolation to the rock. Therefore, two conditions must prevail: (1) an absorption area capable of supplying the amount of water desired; and (2) a rock condition that will permit its movement to the well.

In general, limestone water can be secured in fair quantities in Kankakee, Will, and the southern part of Cook County, DuPage, Kane, Kendall, Grundy, Livingston, LaSalle, Lee, DeKalb, Ogle, and the eastern part of McHenry and eastern part of Lake county. Limestone water is also obtainable along the valley of the Rock river.

While water supplies for rock wells exsit in the counties in the western portion of this zone such supplies are generally obtained from the deeper lying sandstones. The limestones in an area extending from about Harvey on the south to the State line on the north and for a distance of from 5 to 10 miles westerly of the lake shore are quite dense and but little fractured, therefore only small quantities of water can be obtained therefrom.

SUMMARY

To summarize then, it may be said that ground water at suitable low temperature and in sufficient quantities for use as the cooling agent in air conditioning units, particularly when refrigerating equipment is not used, for relatively large buildings such as theaters, churches, stores, court houses, city halls, and office buildings, is extremely hard to find in the southern third of the state.

Conditions are somewhat better, in that portion of the central third of the state east of the Illinois river but west of the river the area is in the same general classification as is the southern third.

The opportunities for obtaining cold ground water are best in the northern third of the state.

The opportunity to obtain ground water is not always a certainty and some study should be given to the problem before embarking on a program of expenditures.

STUDY OF THE USE OF WATER IN COOLING THE RESEARCH RESIDENCE*

By A. P. Kratz,† M. K. Fahnestock,‡ S. Konzo,§ and E. L. Broderick**

This paper is a resume of results obtained at the Research Residence in Urbana, Illinois incident to a coöperative investigation sponsored by the University of Illinois, the American Society of Heating and Ventilating Engineers, and the National Warm Air Heating and Air Conditioning Association. A more complete discussion of these results was presented as a previous paper[1] before the American Society of Heating and Ventilating Engineers.

Previous investigations in summer cooling in the research residence during the summers of 1932, 1933, and 1934 made use of either ice as the medium for cooling water circulated through coils placed in the forced-air heating system or a two-ton mechanical refrigerating unit used in connection with evaporator coils placed in the forced-air heating system. The investigation for the summer of 1935 was undertaken to determine to what extent water from the city water mains, available at a temperature of 58 deg. F., could be used to produce satisfactory cooling and dehumidification in the research residence when supplemented by the circulation of outdoor air through the second story at night and when approximately one air

* Presented before the Illinois Section.

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[1] A.S.H.V.E. research paper, "Study of Summer Cooling in the Research Residence Using Water from the City Water Mains" by A. P. Kratz, M. K. Fahnestock, S. Konzo, and E. L. Broderick, A.S.H.V.E. Journal section. *Heating, Piping* and *Air Conditioning*, May, 1936, pp. 278–288.

change per hour of outdoor air was used for the purpose of ventilation during the day.

DESCRIPTION OF THE RESEARCH RESIDENCE AND COOLING EQUIPMENT

For the purpose of this investigation the Research Residence, shown in figure 1, was equipped with awnings at all east, south, and west windows, and the sunroom was isolated from the rest of the house by closing the doors leading into the dining room. The entire third story was regarded as an attic, and during the daytime was

FIG. 1. VIEW OF RESEARCH RESIDENCE IN URBANA, ILL.

isolated from the rest of the house by closing the door at the head of the stairs. The attic windows, however, were opened to provide ventilation in the attic both day and night. The residence as tested was equivalent to a two-story frame structure with a floored attic. The walls were of standard frame construction and were not insulated.

The arrangement of the forced-air duct system and fan is shown in figure 2. For the purpose of this investigation, all return ducts with the exception of the central one containing the cooling coil were blocked. The delivery ducts to the sunroom and third story were

blocked, as indicated, and the dampers in the ducts to the first and second stodies were adjusted to maintain the proper balance between the amounts of cooling required on these two stories.

The arrangement of the cooling plant is shown in figure 3. The cooling coil consisted of 8 rows of finned tubes and one row of tubes without fins. Each row consisted of 12 tubes connected into headers or return bends at the ends of the tubes. These headers were connected in such a way that the water flowed across the duct through

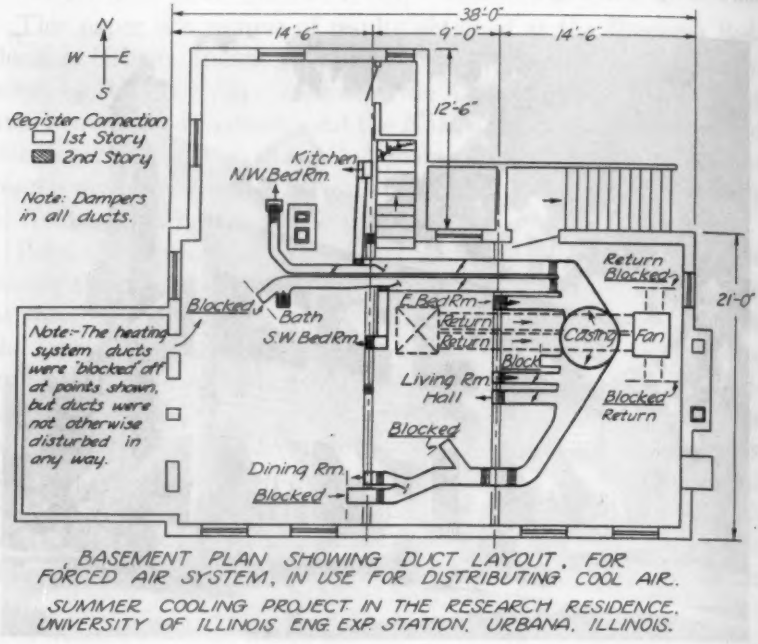

FIG. 2. BASEMENT PLAN SHOWING DUCT LAYOUT FOR FORCED-AIR SYSTEM IN USE FOR DISTRIBUTING COOL AIR

one row of twelve tubes and returned through the next row, thus alternating through each succeeding row of tubes. The water connections were made so that the flow of the water was counter to the flow of the air, thus providing that the coldest air came in contact with the tubes containing the coldest water. The water from the city service main passed through a calibrated water meter before entering the coil. The tubes were $\frac{5}{8}$ in. outside diameter and had 8 fins per inch. The overall diameter including the fins was $1\frac{7}{16}$ in. As arranged in the duct, the gross face section of the coil was $17\frac{9}{16}$ in.

high and 35½ in. wide, giving a gross face area of 4.33 sq. ft. The net face area was 3.56 sq. ft. The net free area was 1.76 sq. ft. The total area of cooling surface, including the row without fins was 429 sq. ft., and based on a volume of air circulated of 1277 cu. ft. per min. the gross face velocity was 295, the net face velocity was 359 and the velocity through the net free area was 726 ft. per min.

The selection of the cooling coil was based on the following considerations. Previous tests with a mechanical refrigerating unit in the research residence had indicated an actual maximum cooling load of approximately 30,000 B.t.u. per hr., of which 22,000 was sensible heat and 8,000 was latent heat load. Since, in the case of cooling with water, no additional load corresponding to the heat loss from the condensing unit and motor would be imposed, it was considered that these figures could be reduced approximately 10 per cent, and a total cooling load of 27,000 B.t.u. per hr. consisting of 20,000 B.t.u. sensible heat and 7,000 B.t.u. latent heat was assumed as a basis for the selection of the water coils. It was further considered desirable to operate the house with a room temperature of 80 deg. F. dry bulb and with the air leaving the registers at approximately 70 deg. F. Since the temperature rise in the ducts between the coil and the registers had been found to be approximately 4 deg. F., the air was required to leave the coil at a temperature of 66 deg. F. The admission of one air change per hr. from outdoors to serve as ventilating air raised the temperature of the air entering the coils to approximately 81 deg. F. The probable temperature drop through the coil would therefore be 15 deg. F. From this temperature drop and the 20,000 B.t.u. per hr., the amount of air to be circulated was calculated as 5,560 lb. per hr. or approximately 1300 cu. ft. per min. The temperature of the available service water was approximately 60 deg. F., and a rise of 10 deg. F. in the water passing through the coil was assumed. From this rise and the total cooling load of 27,000 B.t.u. per hr., the probable water requirement was determined as 324 gal. per hr.

From the manufacturer's catalog a stock coil unit was selected such that with 1300 cu. ft. of air flowing per min. a net face velocity of 365 ft. per min. would be obtained. With this unit the water velocity was estimated as 0.556 ft. per sec., and from the temperatures of the entering and leaving air and water, the logarithmic mean temperature difference was calculated as 8.26 deg. F. Following the manufacturer's recommendation, the heat transmission was based on the sensible heat alone. The overall heat transmission coefficient of

5.60 B.t.u. per sq. ft. per degree mean temperature difference per hr., corresponding to a water velocity of 0.556 ft. per sec. and an air velocity of 365 ft. per min. was selected from the manufacturer's published data. The sensible cooling load of 20,000 B.t.u. per hr. required 433 sq. ft. of coil surface and this condition was approximately satisfied by 8 rows of tubes in the type of coil used.

The operation of the cooling plant was controlled by means of a thermostat located at the 60-in. level in the hall on the second story. This thermostat was used in connection with a motor-operated, water-valve placed on the outlet side of the cooling coil to start and stop the flow of water through the coil. The valve was either open or closed and moved slowly enough to prevent any water hammer.

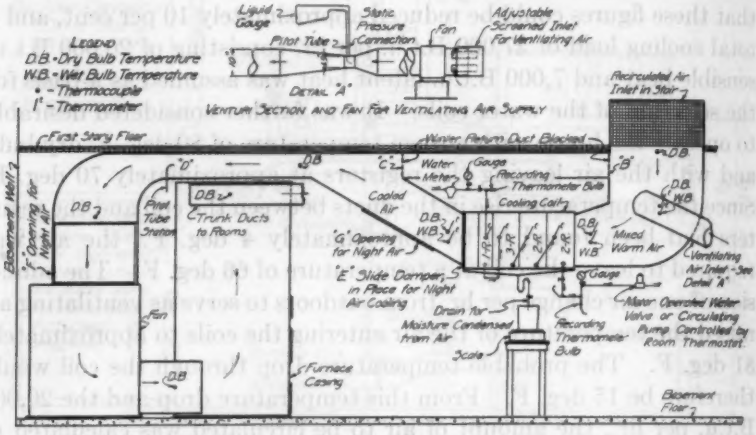

FIG. 3. DIAGRAM OF COOLING PLANT WITH WATER COOLING COIL

In order to provide for both heating in the winter and cooling in the summer, the cooling coil was installed in a by-pass in the central return duct as shown in figure 3. For the summer work, the duct was blocked with tightly fitting dampers at B and C, and all of the air delivered by the fan in the forced-air heating system passed through the cooling coil when the air in the house was being recirculated. For the purpose of providing outdoor air for cooling during the night the basement door and the door, G, in the recirculating duct were opened, and the slide damper, E, was closed. The fan in the forced-air system was driven by a V-belt from a $\frac{3}{4}$ horsepower motor and delivered approximately 1,300 cu. ft. of air per min. when recirculating the air in the house and 2300 c.f.m. when using outdoor air at night. Out-

door air, for the purpose of ventilation during the day, was provided by means of the duct shown as detail A in figure 3. This duct contained a venturi section for the measurement of the volume of air delivered, and it was necessary to use a small auxiliary fan in order to deliver the equivalent of approximately one air change per hour. Wet and dry bulb temperatures of the air entering and leaving the cooling coil were measured by means of thermometers. The temperature of the water at inlet, at outlet and at intermediate points was measured by means of thermometers as shown in figure 3. The locations of thermometers and thermocouples for measuring the temperature of air at other points and the location of Pitot tubes for measuring the air quantities are also shown in this figure.

METHOD OF CONDUCTING TESTS

During the summer continuous records were made, by means of temperature recorders, of the outdoor air temperature and the temperatures at nine points in the residence. Continuous records were also made of the temperatures of the air entering and leaving the cooling coil, the water entering and leaving the cooling coil, the outdoor air taken in for ventilation and the wet and dry bulb temperature of the outdoor air on the north side of the house. Other incidental air temperatures and relative humidities were read at regular intervals.

During the periods of operation, observations were made of the weight of water circulated through the cooling coil, the temperature of the water entering and leaving the coil, the weight of water condensed from the air and the electrical input to the fan motor. The weight of water circulated was obtained by means of a calibrated water meter and the air quantities were obtained from traverses made with Pitot tubes at section D in the central return duct and at the venturi section in the ventilating air duct as shown in figure 3.

During all of the tests the windows on the first story remained closed. The windows in the attic remained open. For the purpose of cooling with outdoor air at night, 11 windows on the second story were opened by raising the lower sash to the full extent. For most of the tests the Residence was operated on the following schedule:

The second story windows and the attic and basement doors were closed at 7 a.m. and the dampers were changed so that the fan, which had been delivering outdoor air through the system, started delivering recirculated air and the outdoor air admitted for ventilation. The

former was equivalent to 4.4 recirculations of the air in the house, and the latter was equivalent to one air change per hour, making a total of 5.4 air changes per hour, delivered by the fan. The fan was allowed to run continuously during the day. When the temperature of the indoor air on the second story rose to 81 deg. F the motor driven valve actuated by the thermostat admitted water to the cooling coil. The cooling plant was allowed to operate with thermostatic *on* and *off* control maintaining 81 deg. F on the second story until the effective temperature outdoors became equal to the effective temperature on the second story indoors. The water valve was then closed; the second story windows and attic door were opened; and the dampers were set and the basement door opened, so that the fan delivered outdoor air through the duct system, the fan continuing to run until 7 a.m. The fan delivery was 2300 c.f.m. or 9.74 air changes per hour.

During the latter part of the season this schedule was modified by maintaining an effective temperature of approximately 74 deg. instead of a dry bulb temperature of 81 deg. F. This was accomplished by controlling the plant manually and starting the flow of water through the coil whenever the relative humidity increased sufficiently so that with the prevailing dry bulb temperature the effective temperature rose above 74 deg.

RESULTS OF TESTS

General Conditions. The operating characteristics of the cooling plant and a comparison of the actual and calculated cooling loads for the house can best be illustrated by the results obtained on a typical day. For this purpose a test made on August 2, 1935, was selected and the results are shown in table 1 and figure 4.

On the typical day selected, the outdoor temperature was 95.0 deg. F at 2 p.m. and reached a maximum of 96.0 deg. F. at 2:30 p.m. At this time the house was being operated with a constant dry bulb temperature of approximately 80 deg. F., and the windows on the second story had been opened and outdoor air circulated on the previous night. The air conditions at different locations are given in the first eleven items of table 1. The dry bulb temperature on the second story was only 0.6 deg. F. higher than that on the first, thus indicating a satisfactory balance of the cooling on the two stories. The temperature of the cooled air leaving the registers was approximately 70 deg. F., and no difficulty was experienced from drafts in the rooms. The rise in temperature of the air passing

TABLE 1

Typical Operating Data and Results Obtained by Cooling With Water, at 2:00 P.M. on August 2, 1935[a]

1. Outdoor air	D.B.[b] 95.0 F, W. B. 78.6 F, D.P. 72.5 F
Humidity	R.H. 48.5%, S.H. 120.8 grains per pound dry air
2. Indoor air, aver. breathing level temperature	1st story 79.1 F, 2nd story 80.5 F
3. Indoor air, house aver. at breathing level	D.B. 79.8 F, W.B. 70.9 F, D.P. 67.2 F
Humidity	R.H. 65%, S.H. 99.8 grains per pound dry air
4. Indoor air, entering return grille	D.B. 77.7 F, W.B. 69.8 F, D.P. 66.2 F
Humidity	R.H. 67.5%, S.H. 96.8 grains per pound dry air
5. Ventilating air	D.B. 91.6 F, W.B. 76.2 F, D.P. 70.1 F
Humidity	R.H. 49.5%, S.H. 111.0 grains per pound dry air
6. Mixed air entering cooling coil	D.B. 80.3 F, W.B. 70.7 F, D.P. 66.5 F
Humidity	R.H. 62.8%, S.H. 97.5 grains per pound dry air
7. Mixed air leaving cooling coil	D.B. 65.8 F, W.B. 64.7 F, D.P. 64.1 F
Humidity	R.H. 94.0%, S.H. 89.7 grains per pound dry air
8. Air temperature drop through cooling coil, F	14.5
9. Temperature of cooled air leaving registers, 1st and 2nd story aver., F	70.2
10. Air temperature rise in ducts and casing, F	4.4
11. Basement air temperature at breathing level, F	75.2
12. Quantity of air circulated through wet coils.	1,277 cfm or 5,547 lb of dry air per hour
Density of air, pound, per cubic foot	0.0724
13. No. of house air recirculations per hour	5.4
14. Ventilating air	238 cfm or 1005 lb of dry air per hour
Density of air, pounds, per cubic foot	0.0704
15. Cooling coil	gross face area 4.33 sq ft net free area 1.76 sq ft
Surface of cooling coil, square feet	429
Air velocity, feet per minute	gross face 295, net face 359, free area 726
16. Moisture condensed from air, pounds per hour	5.83
17. Heat given up by the air; total	25,440 Btu per hour
Heat due to moisture in air	6,120 Btu per hour; 24.0% of total heat absorbed
Sensible heat	19,320 Btu per hour; 76.0% of total heat absorbed
18. Water temperature through cooling coil, F.	Inlet 58.3, Outlet 66.2, Rise 7.9
19. Rise in water temperature through coil, F	One row 0.8, Four rows 4.2, Six rows 5.5 Eight rows 7.9
20. Water pressure at coil, pounds per square inch	Inlet 20.5, Outlet 20.0
21. Quantity of cooling water per hour	Pounds 3000.6, Gallons 360
22. Heat absorbed by water passing through cooling coil, Btu per hour	23,700
23. Recirculating fan data	Speed 477 rpm
Motor	Size ½ hp, Measured power rate 0.44 kw
24. Static pressure loss through coils	Wet 0.28 in. water, Dry 0.23 in. water
25. Total resistance of system	0.51 in. water

[a] Test number 13, series 1-35.

[b] Abbreviations used: D.B. = Dry-Bulb temperature; W.B. = Wet-Bulb temperature; D.P. = Dew Point temperature; R.H. = Relative Humidity; S.H. = Specific Humidity.

through the furnace casing and ducts was 4.4 deg. F. The quantity of air circulated was 1347 c.f.m. when the coils were dry. Increased frictional resistance when condensation was present on the coil sur-

faces, however, decreased this amount to 1277 c.f.m. With this amount of air, which represented 5.4 recirculations per hour, the velocity through the net face area was 359 ft. per min. and the temperature drop through the coil was 14.5 deg. F. This corresponded closely with the 365 ft. per min. and 14.0 deg. F. drop used for the

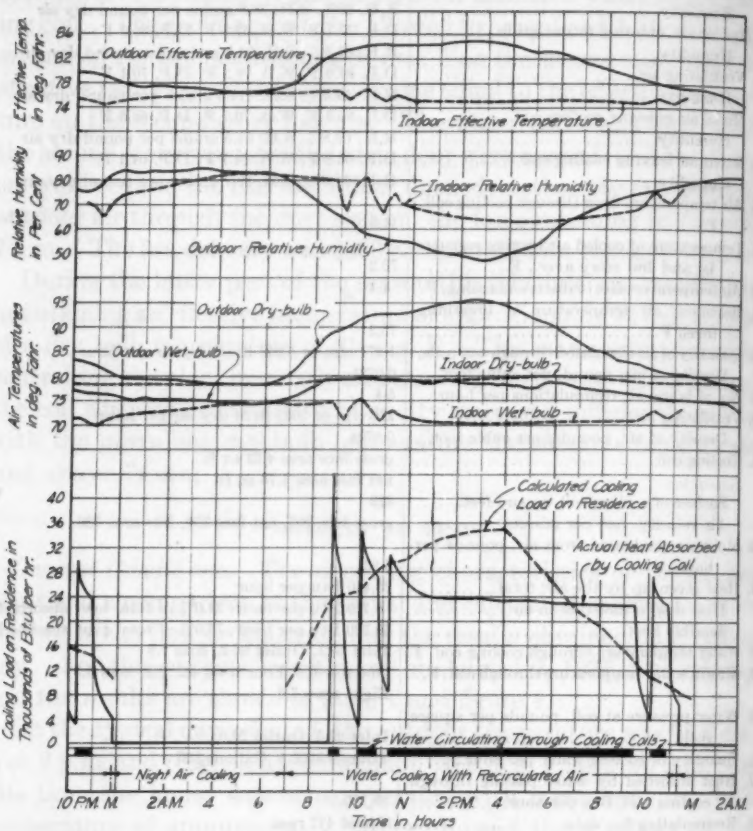
Effective Temp. in deg. Fahr.
Outdoor Effective Temperature
Indoor Effective Temperature
Relative Humidity in Per Cent
Indoor Relative Humidity
Outdoor Relative Humidity
Air Temperatures in deg. Fahr.
Outdoor Dry-bulb
Outdoor Wet-bulb
Indoor Dry-bulb
Indoor Wet-bulb
Cooling Load on Residence in Thousands of B.t.u. per Hr.
Calculated Cooling Load on Residence
Actual Heat Absorbed by Cooling Coil
Water Circulating Through Cooling Coils
Night Air Cooling
Water Cooling With Recirculated Air
10 P.M. M. 2 A.M. 4 6 8 10 N 2 P.M. 4 6 8 10 M 2 A.M.
Time in Hours

FIG. 4. ACTUAL AND CALCULATED COOLING LOAD ON RESIDENCE AND TEMPERATURES, TEST NO. 13, SERIES 1-35, AUGUST 2, 1935; WITH NIGHT AIR COOLING.

selection of the coils. The free area velocity of 726 ft. per min. did not prove to be sufficient to carry any condensed moisture away from the surfaces of the cooling coil.

Cooling Load. Since the cooling coil was well lagged with corkboard to prevent heat gain, it was possible to obtain the actual cool-

ing load either from the heat given up by the mixture of air and water vapor or from the heat absorbed by the water passing through the coil. By using corrected wet-bulb readings to determine the enthalpy of the moist air entering and leaving the coil it was possible to obtain a heat balance between the air and water within approximately 8 per cent. This method of calculation, however, does not show the distribution between sensible and latent heat loads. This distribution was obtained, as shown in item 17, table 1, by using the corrected values for the dry-bulb temperatures, and by multiplying the weighed amount of condensation from the coil by a constant representing the heat given up by the change in moisture content of the air per pound of water vapor condensed. This latter amounted to 1,050 B.t.u. per pound of vapor condensed. The total of the heat given up by the air as computed by this method was within 6 percent of the calculated heat absorbed by the water. It may be noted, that on all tests having a duration exceeding 4 hours, the moisture load varied from 20 to 31 percent of the total load.

Operating Characteristics with Constant Dry-bulb Temperature. The operating characteristics with a constant dry bulb temperature in the rooms of approximately 80 deg. F. are shown in figure 4, for a day on which the outdoor temperature rose to a maximum of 96 deg. F. During the night before, when the second story windows were opened and outdoor air was circulated, the indoor dry-bulb temperature dropped to 78 deg. F. and remained at this value until 7:00 a.m., when the windows were closed and the dampers were changed to recirculate the air in the house. The dry-bulb temperature rose to 79 deg. F. at 8:50 a.m. at which time the thermostat opened the water valve. The plant then operated intermittently until 11:20 a.m., and continuously from 11:20 a.m. to 9:30 p.m. maintaining the dry-bulb temperature between 79 and 80 deg. F.

At 8:50 a.m. the wet-bulb temperature was 75 deg. F., corresponding to a relative humidity of 80 percent. When the plant started the relative humidity dropped to 67 percent, but rose again to 81 percent almost immediately after the water valve closed. This alternate decrease and increase of relative humidity in the house was characteristic of the intermittent operation of the plant. When the plant operated continuously, however, as from 11:20 a.m. to 9:30 p.m., the relative humidity stabilized at between 63 and 66 percent, representing an effective temperature of approximately 75 deg. During the intermittent periods the effective temperature was at

times as high as 77 deg. That is, on a warm day, when the plant operated continuously, conditions were just on the upper borderline for comfort, but during the periods of intermittent operation the effective temperature was distinctly too high for comfort. The significance of this type of operation on a milder day will be referred to later, but conditions shown in figure 4 indicated that for 58 deg. F. service water, with which it was not found possible to obtain the relative humdity lower than 62 percent, the dry-bulb temperature should be maintained somewhat lower than 80 deg. F.

The calculated cooling load was greater than the actual load during the period from 11:15 a.m. to 6:30 p.m., rising to a maximum value of 38,000 B.t.u. per hr. at 2:30 p.m. as compared with an actual load of 24,000 at the same time. After 6:30 p.m. the calculated load became less than the actual load.

During the periods of intermittent operation the actual cooling load curve showed high peaks at the start of each operating period. These peaks correlated with periods of high indoor relative humidity, indicating that periods of high wet-bulb temperature for the air entering the coil were accompanied by corresponding periods of comparatively high heat transmission for the coil. An explanation for this correlation is offered by figure 5.

Heat Transmission of Coils. The upper curve in figure 5 shows that the heat absorbed by the coil was practically a linear function of the enthalpy of the entering air. C. J. Scanlan[2] has shown this to be true for a different type of coil when the velocity of the air and the mean temperature of the refrigerant in the coil were maintained constant.

During these tests a constant indoor dry-bulb temperature was maintained, resulting also in a practically constant dry-bulb temperature for the air entering the coil. Hence, periods of high relative humidity also represented periods of high wet-bulb temperature with corresponding high enthalpy for the air entering the coil; and since figure 5 shows that high heat transmission accompanied high enthalpy for the air entering the coil, it also serves to explain the fact that the peaks in the load curve in figure 4 occurred at times corresponding to high indoor relative humidity.

The curves in figure 6 show that during periods of continuous operation, both in the case of the water coil used in the study in

[2] "Performance of Extended Cooling Surfaces," by C. J. Scanlan, Refrigerating Engineering, Vol. 27, No. 4, April, 1934, pp. 197–199.

1935 and in the case of the mechanical refrigerating unit used in the study of 1934, the indoor specific humidity maintained was dependent only on the temperature of the medium used and the character of the cooling coil and was independent of the amount of water vapor in the outdoor air. Since in both cases a constant indoor-dry-bulb temperature of 80 deg. F. was maintained, the specific humidity is also representative of the indoor relative humidity. That is, the water coil used in 1935 with a mean water temperature of approxi-

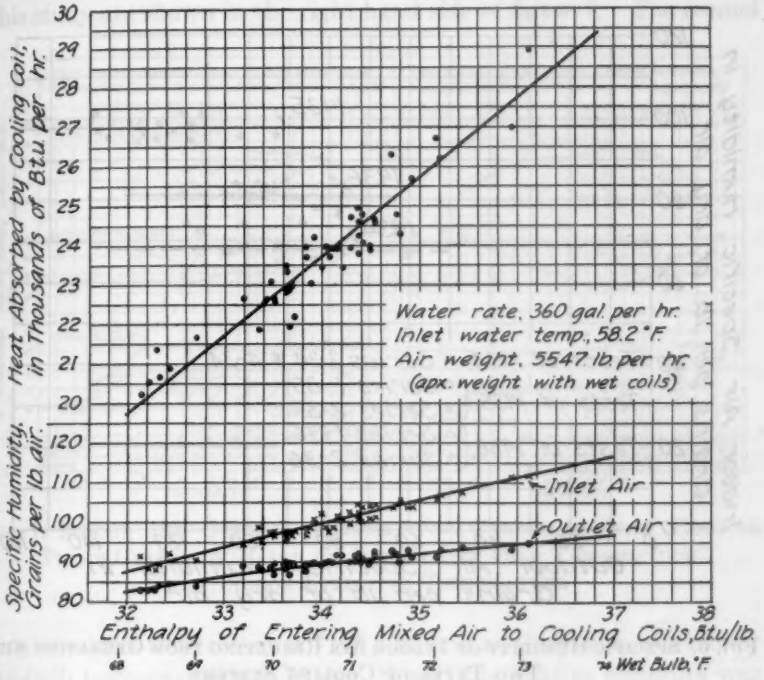

FIG. 5. PERFORMANCE OF COOLING COILS

mately 62 deg. F. maintained a constant indoor relative humidity of 63 percent during periods of continuous operation, while the evaporator coil used in 1934 with a mean temperature of approximately 45 deg. F. for the refrigerant maintained a constant relative humidity of 45 percent.

During periods of operation the ventilating air from outdoors was mixed with the recirculated air from the house just before entering the cooling coil. The moisture content of the outdoor air therefore

directly influenced that of the mixed air entering the coil. The lower curves in figure 5 indicate that the enthalpy of the entering air increased as the specific humidity increased, resulting in an increase in the heat transmission for the coil. At the same time the specific humidity of the air leaving the coil increased, but not to as great an extent as that of the inlet air. This indicates that a part, if not all, of the increase in heat transmission was utilized in increasing the amount of condensation as the specific humidity of the outdoor air and hence that of the air entering the coil, was increased.

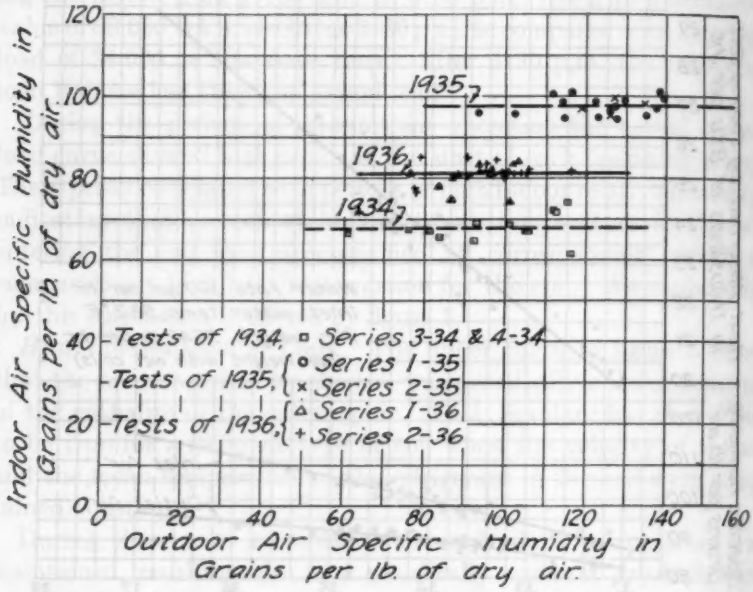

FIG. 6. SPECIFIC HUMIDITY OF INDOOR AIR RESULTING FROM OPERATION WITH TWO TYPES OF COOLING SYSTEMS

Thus the increasing heat transmission of the coil tended to compensate for increases in the outdoor specific humidity, and, as a result, also tended to maintain a constant indoor relative humidity during periods of continuous operation, as shown in figure 6.

Operating Characteristics with Constant Effective Temperature. Figure 7 shows the performance of the residence on two mild days, during which the operation of the plant was intermittent and no long periods of continuous running occurred. The left hand side shows the operation on a day on which the outdoor temperature rose

to a maximum of 87 deg. F. and a constant indoor dry-bulb temperature of approximately 80 deg. F. was maintained. Owing to the short operating periods, the indoor relative humidity ranged from 68 to 80 per cent with corresponding indoor effective temperatures of from 76 to 77.5 deg. At no time could the conditions be regarded as comfortable. A study was therefore made on a similar day on which the maximum outdoor temperature rose to 86 deg. F. and during which the plant was manually controlled to maintain an indoor effective temperature not to exceed 76 deg. The results of this study are shown in the right hand side of figure 7. The second

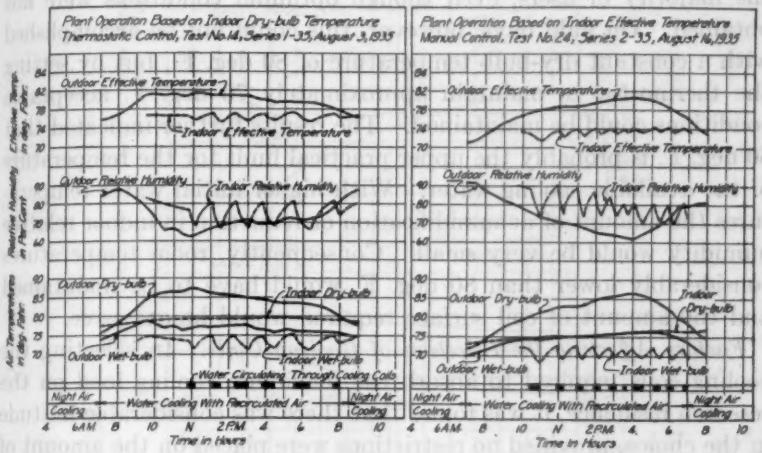
Plant Operation Based on Indoor Dry-bulb Temperature
Thermostatic Control, Test No.14, Series 1-35, August 3, 1935
Plant Operation Based on Indoor Effective Temperature
Manual Control, Test No.24, Series 2-35, August 16, 1935
Outdoor Effective Temperature
Indoor Effective Temperature
Outdoor Relative Humidity
Indoor Relative Humidity
Outdoor Dry-bulb
Indoor Dry-bulb
Outdoor Wet-bulb
Indoor Wet-bulb
Water Circulating Through Cooling Coils
Night Air Cooling
Water Cooling With Recirculated Air
Night Air Cooling
Time in Hours

FIG. 7. INDOOR AND OUTDOOR TEMPERATURE CONDITIONS WITH COOLING PLANT OPERATION BASED ON INDOOR DRY-BULB TEMPERATURE AND INDOOR EFFECTIVE TEMPERATURE

story windows were closed at 7:00 a.m. and at 10:00 a.m. the indoor dry-bulb temperature was 75 deg. F. and the relative humidity was 90 percent, corresponding to an effective temperature of 74 deg. The plant was then started and the relative humidity decreased to 74 percent giving an effective temperature of 72 deg. at 11:00 a.m. at which time the plant was stopped. Subsequent to this the plant was started manually whenever the effective temperature approached 74 deg. with the prevailing dry-bulb temperature and was stopped whenever the effective temperature dropped to 73 deg. With this method of operation the indoor dry-bulb temperature gradually increased to 77 deg. F. and the relative humidity decreased to vary

between 70 and 80 percent during the on- and off-periods of operation. By this means comparatively comfortable conditions were maintained in the house during the entire day.

The results of these studies indicate that it would be desirable to develop a means of control operating directly on effective temperature. With 58 deg. F. service water available, and with a constant dry-bulb temperature of 80 deg. F. maintained, on warm days, when the maximum outdoor temperature rose above 90 deg. F., and when the plant could operate continuously, a material improvement in atmospheric conditions was effected that would be acceptable to the majority of users, even though optimum conditions were not obtained. On mild days, however, this could not be accomplished with a constant dry-bulb temperature of 80 deg. F., but by setting the thermostat to maintain approximately 76 deg. F. acceptable conditions could be maintained. The results further indicated that 60 deg. F. is probably the upper practical limit for the temperature of the available cooling water. With higher initial water temperatures the amount of dehumidification or reduction in indoor relative humidity would be very small. Consequently, room temperatures considerably lower than 80 deg. F. would have to be maintained and the amount of coil surface required would be excessive.

Factors Affecting the Selection of Cooling Coils. In selecting the cooling coils required to absorb the maximum cooling load on the research residence, it was found that there was considerable latitude in the choice, provided no restrictions were placed on the amount of cooling water or the amount of coil surface used. The cooling load was estimated as 20,000 B.t.u. per hr. sensible heat and 7,000 B.t.u. per hr. latent heat. With 80 deg. F. maintained in the rooms, the restriction of 70 deg. F. for the temperature of the air leaving the registers, together with the known rise of 4 deg. F. in the duct system, determined that the temperature drop of the air passing through the coil should be 15 deg. F.; or from 81 deg. F. to 66 deg. F. This drop in temperature, together with the sensible heat load, limited the air requirement to 1300 c.f.m. A net face velocity of 365 ft. per min. permitted the use of an air duct of reasonable dimensions, and thus fixed the face area of the coil. The freedom of choice then proved to be in the amount of coil surface, or the number of rows of coil to be used.

The curves in figure 8 were computed from the data furnished by the manufacturer of the coils, and indicate that the required tem-

perature drop in the air could be obtained either by the use of a large amount of cooling water with a small amount of coil surface, or by a small amount of water in connection with a large amount of coil surface. Furthermore, the resistance to the flow of air increased rapidly as the amount of surface, or number of rows of coil increased. In addition to the possible limit imposed on the air delivery by the

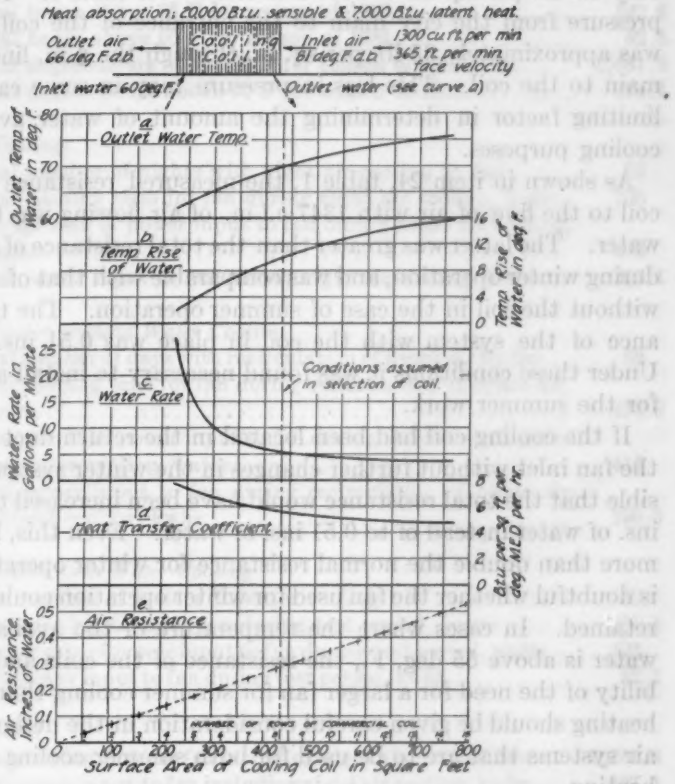
Heat absorption: 20000 B.t.u. sensible & 7000 B.t.u. latent heat.
Outlet air 66 deg. F. d.b.
Cooling Coil
Inlet air 81 deg. F. d.b.
1300 cu. ft. per min.
365 ft. per min. face velocity
Inlet water 60 deg. F.
Outlet water (see curve a)
a Outlet Water Temp.
b Temp. Rise of Water
c Water Rate
d Heat Transfer Coefficient
e Air Resistance
Conditions assumed in selection of coil
Outlet Temp. of Water in deg. F.
Temp. Rise of Water in deg. F.
Water Rate in Gallons per Minute
B.t.u. per sq. ft. per deg. M.E.D. per hr.
Air Resistance, Inches of Water
Number of Rows of Commercial Coil
Surface Area of Cooling Coil in Square Feet

FIG. 8. COMPUTED PERFORMANCE CHARACTERISTICS FOR ONE TYPE OF COOLING COIL

higher resistance, the use of a large amount of surface has the further disadvantage of high first cost. On the other hand, the use of a small amount of coil surface has the disadvantage of high operating cost due to the amount of water used. Under these conditions a compromise is necessary. In the case of the research residence, this was effected by selecting 8 rows of coils. As shown by the water

rate curve in figure 8, this determined a water rate such that a decrease of one or two rows would have resulted in an appreciable increase in water consumption, while an increase of one or two rows would not have resulted in an appreciable decrease in water consumption.

The resistance offered by the coil itself to the flow of water was only 0.5 lb. per sq. in. as shown in item 20 of table 1. The drop in pressure from the city main to the entrance of the coil, however, was approximately 35 lb. per sq. in. through the $\frac{3}{4}$ in. line from the main to the coil. This loss in pressure may in some cases be the limiting factor in determining the amount of water available for cooling purposes.

As shown in item 24, table 1, the measured resistance of the dry coil to the flow of air with 1347 c.f.m. of air flowing was 0.23 ins. of water. The latter was greater than the total resistance of the system during winter operation, and was comparable with that of the system without the coil in the case of summer operation. The total resistance of the system with the coil in place was 0.51 ins. of water. Under these conditions it was found necessary to install a larger fan for the summer work.

If the cooling coil had been located in the return duct just above the fan inlet without further changes in the winter system, it is possible that the total resistance would have been increased to only 0.41 ins. of water instead of to 0.51 ins. of water. Even this, however, is more than double the normal resistance for winter operation, and it is doubtful whether the fan used for winter operation could have been retained. In cases where the temperature of the available service water is above 55 deg. F., the resistance of the coils and the possibility of the need for a larger fan for summer cooling than for winter heating should be given careful consideration in the design of forced-air systems that are to be used for both summer cooling and winter heating.

Summary of Seasonal Results. Table 2 gives a summary of the total quantities obtained for the season of 1935. The total of 1081.8 degree-hours above 85 deg. F. indicates that this season was mild as compared with those for 1934, 1933, and 1932, for which the degree-hours above 85 deg. F. were 2657.5, 2309.3, and 1470.7 respectively. This was caused by the comparatively small number of days on which the outdoor temperature rose above 90 deg. F. The hours above 85 deg. F. for this season were 322.6 as compared with 481.5,

493.2 and 329.1 for 1934, 1933, an 1932, while the hours above 90 deg. F. were only 82.5 as compared with 224.1, 208.4, and 121.8

TABLE 2

Summary of Results of Tests Using Water for Cooling and Using Night Air Cooling for Entire Season of 1935

Weather Data	
1. Total hours above 85 F for season of 1935	322.6
2. Total hours above 90 F for season of 1935	82.5
3. Total degree-hours above 85 F for season of 1935	1,081.9
4. Total degree-hours above 90 F for season of 1935	174.1
Night Air Cooling	
5. Total number of nights with night air cooling by fan	63
6. Total running time for fan during night air cooling, hours	706
7. Average rate of power input to fan during night air cooling, watts	443
8. Total power input to fan during night air cooling, kwhr	313.1
Air Recirculation without Water Cooling	
9. Total number of days with recirculation of house air by fan	59
10. Total running time for fan during recirculation of house air, hours	474.8
11. Average rate of power input to fan during recirculation without water cooling, watts	415
12. Total power input to fan during recirculation of house air without cooling, kwhr	196.9
Air Recirculation with Water Cooling	
13. Total number of tests with water cooling	32
14. Total running time for fan during test period, hours	201.1
15. Average rate of power input to fan during test period, watts	433
16. Total power input to fan during test period, kwhr	87.1
Combined Totals	
17. Total running time for fan including night air cooling, hours	1,381.8
18. Total power input to fan including night air cooling, kwhr	597.1
19. Total number of hours of test period for season	201.1
20. Total number of hours of water circulation during test period	120.6
21. Total quantity of cooling water, gallons	43,300
cu ft	5,690

respectively for the previous seasons. While the 1935 season was mild from the standpoint of outdoor temperatures, it was characterized by unusually high outdoor humidity. This is indicated to a

certain extent by figure 6 from which it may be observed that the outdoor specific humidity ranged from 92 to 140 grains per lb. of dry air in 1935 as compared with a range of from 60 to 118 grains per lb. for 1934.

From item 6, table 2, it may be observed that the total time that the fan was running during periods when it was circulating air from outdoors at night was 70.6 hours. At the local rate for electrical current of 3.1 cents per kw hr. prevailing in Urbana, Ill. the cost of operating the fan during these periods was 1.37 cents per hr. During the stand-by periods from 7:00 a.m. until the indoor temperature rose to 80 deg. F. the fan was allowed to recirculate the air in the house. As shown by item 10 the total running time for the fan during these periods was 474.8 hrs. During all of the time that cooling was demanded the fan was allowed to run irrespective of whether the water control valve was open or closed. The total time that the fan was running during these periods, as shown by item 14, was 201.1 hrs. The total time during which the fan was operated to recirculate the air in the house was therefore 675.9 hrs., and the cost of operating the fan to recirculate the air in the house was 1.34 cents per hr. The total amount of water actually used during the total running time of 120.6 hrs. was 43,300 gallons. At the prevailing rate of 33 cents per thousand gallons this represented an hourly cost of 11.8 cents per hr. for water alone, or a total hourly cost of 13.1 cents for both water and electricity during the actual time when the water was running.

Owing to wide variations in seasonal demands and in local water and electrical rates, seasonal costs are comparatively meaningless. With restriction of due appreciation of their limitations, however, they are undoubtedly of some interest. During the part of the season over which the plant was in operation the total cost for electricity for operating the fan both to circulate air from outdoors at night and to recirculate the air in the house during the day was $18.52. The total cost for water was $14.29, and the cost for both electricity and water was $32.81. Although the cooling plant was not ready to operate before July 11, observations on the temperatures and conditions in the Residence were made dating from June 1. The first part of the summer, particularly during May, was unusually cool, and these observations indicated that between May 1 and July 11 only 8 days occurred on which any cooling whatever would have been required. If these days are included, a reasonable

estimate of the cost of cooling for the season of 1081.8 degree-hours would be approximately $36.00.

CONCLUSIONS

The following conclusions may be drawn as applying to the Research Residence and the conditions under which the tests were conducted.

(1) Using water from the city mains at 58 deg. F., it is possible to maintain an indoor dry-bulb temperature of 80 deg. F. with the outdoor temperature as high as 100 deg. F. On days when the maximum outdoor temperature exceeds 90 deg. F., the plant will operate continuously over considerable periods of time and it is possible to maintain an indoor relative humidity of 63 percent, with a resultant effective temperature of 75 deg. While not representative of optimum comfort, these conditions do represent a material improvement in atmospheric conditions that would probably be acceptable to the majority of users.

(2) On days when the maximum outdoor temperature does not exceed 90 deg. F. the plant will operate intermittently at all times and the indoor relative humidity will exceed 63 percent. Under these conditions the maintenance of an indoor dry-bulb temperature of 80 deg. F. will result in effective temperatures exceeding 75 deg. and conditions will not be satisfactory from the standpoint of comfort.

(3) On moderately warm days it is possible to operate the plant with 58 deg. F. water from the city mains so as to maintain effective temperatures not exceeding 74 deg. with indoor relative humidities ranging from 70 to 80 percent, and to maintain acceptable conditions from the standpoint of comfort.

(4) With 58 deg. F. water from the city mains it is possible to obtain sufficient dehumidification to maintain 63 percent relative humidity indoors. These results indicate that 60 deg. F. is probably the upper practical limit for the temperature of the available cooling water unless an excessive amount of coil surface is used, in order to maintain indoor dry-bulb temperatures as low as 75 deg. F. in severe weather.

(5) In designing a plant to operate on 58 deg. F. water from the city mains the resistance of the coils to the flow of air and the

capacity of the fan available may become limiting factors in determining the amount of surface and character of the coil to be used.

(6) The resistance of the coil to flow of water is very small, but the pressure loss in the line between the coil and the city main may be large enough to become a limiting factor in determining the amount of water than can be circulated through the coil.

The results presented in this paper were obtained in connection with the summer cooling investigation (1935) in the Research Residence,[3] figure 1, at the University of Illinois, conducted by the Engineering Experiment Station of which M. L. Enger, Dean of the College of Engineering, is the director, in the Department of Mechanical Engineering of which O. A. Leutwiler, Professor of Mechanical Engineering Design, is the head. These results will ultimately comprise part of a bulletin of the Engineering Experiment Station. Acknowledgment is also due to J. S. Cunningham, Research Assistant, for services rendered in connection with the investigation, and to the various manufacturers who cooperated by furnishing instruments and equipment.

[3] The Research Residence in Urbana, Ill., was built, furnished, and completely equipped specifically for research work in warm air heating by the National Warm Air Heating and Air Conditioning Association in December, 1924.

RECORDED USE OF WATER FOR AIR CONDITIONING*

By O. C. Holleran

(Marketing Research Division, U. S. Dept. of Commerce, Washington, D. C.)

Since 1933 the number of air conditioning installations in the United States has increased approximately 1400 percent, while horse power has increased 250 percent from the end of 1932 to the end of 1936. This is an amazing growth, yet the trend of air conditioning sales continues more steeply upward than in any past year. As a result the problems arising out of the use of city water by air conditioning installations have been growing steadily more serious in cities all over the country.

Surveys made by the air conditioning manufacturers indicate that about 40 percent of all air conditioning installations depend upon local city water supplies for their cooling. This being so, it is easily seen that the question of water available for such use will sooner or later become a serious problem. Let me illustrate: the General Electric Company's engineers estimate that one horse power of air conditioning using water at 75 degrees temperature will consume approximately a hundred gallons of water per minute. On this basis the present water-using air conditioning equipment of the country running at maximum capacity has a potential demand of more than seven hundred billion gallons of water annually, or more than the combined pumpage of New York and Chicago in 1936.

While the figures given are naturally a great deal higher than any actual demand which will accrue from the present equipment, they do tend to demonstrate the immense volume of water susceptible to use for air conditioning, and point out the definite need for a survey of the actual situation in every individual community and the probable effect of air conditioning demand upon the local water supply.

In many communities the demand for water for air conditioning use has already become a serious one, either in the community as a whole

* Presented at the Buffalo Convention, June, 1937.

or in some particular section of the city. This we know from the records of the Chicago and other water authorities who have measured and segregated the problem. Yet one of the remarkable facts developed in the recent survey, made by the Bureau of Foreign and Domestic Commerce of the water supply available for air conditioning in the metropolitan communities of the country was the lack of detailed knowledge of the situation which the water authorities have at their call.

For instance, thirty-eight cities specified that the demand for water for air conditioning in their communities was sufficiently large to cause the city authorities to place some form of limitation on water use, or to be at present seriously considering such limitation. Yet only six cities were able to state definitely the number and type of air conditioning installations in their communities and how much water these installations were using. It would appear, therefore, that in many of the cities where there has been a very high increase in the use of water during the past two or three years, the city water authorities and other city officials are assuming that much of this increase is due to air conditioning use without actually having the facts before them.

There are a few cities like Atlanta, Georgia; St. Paul, Minnesota; and Dallas, Texas, where normal demand is already up to the capacity of the system to deliver. In these places the current lack of data on air conditioning use of water is not an immediately serious one, since there must be an extension of water works facilities before any increase in demand for water can be met. They should plan to obtain complete data, however, as a help to estimating future growth of demand.

There is a second group of cities including such major centers as Pittsburgh, Hartford, and Philadelphia, which are using 75 to 96 percent of the present capacity of their water systems. Since the demand for air conditioning is growing with such rapidity, it is obviously important that the water works officials in this group of cities should move as rapidly as possible to obtain a complete picture of the situation in their communities.

It is equally true that all cities, regardless of size or of the unimportance of present air conditioning water demand upon them, should plan to obtain similar facts regarding their own water use problem, as a safeguard against a sudden shortage.

One of the things which, it appears, has hampered the gathering

of such data is the fact that in many cities permits for air conditioning installations must be obtained from the city electrical officials. In other cities it would appear that such permits are issued by the sanitary authorities and in others the water officials are the licensing group. Since the use of water by air conditioning plants is more important from the point of view of the city than any other factor involved, it would appear that some arrangement should be made in every community to obtain immediately a complete survey of present installations showing type of plant, whether non-water using, using water towers or other equipment to conserve the consumption of water, or using water. In the last case, the source whether from the city supply or private wells should be shown.

The survey should also include information on the disposal of waste water, since the great gallonage discharged by a number of air conditioning installations, even though they are individually small, may easily create a very severe and expensive sewerage disposal problem.

The survey should also show the installed horse power of the equipment, the tonnage of refrigeration delivered and the gallonage of water used per minute.

Once this survey is completed, the city water authorities will have a definite picture of their immediate problem and by obtaining complete information on each future installation, the engineers responsible for the water situation will always know definitely what the need for regulation and limitation may be.

Without such facts any estimates of water use by air conditioning equipment are purely guesswork and action by the city on such estimates may very well place the water service in an embarassing position, especially if on the basis of such estimates, the city should limit the use of air conditioning equipment because of water consumption and the air conditioning dealers were able to show that the water was being used for some other purpose.

FRAZIL ICE PROBLEMS IN PUMPING STATIONS*

By Robert Dorion

(*City Engineer, Lachine, Que.*)

You are all well familiar with the regular, tiresome and permanent noise of motors in a pumping station. One easily gets accustomed to such noise and, whoever works in a plant of such nature can readily tell by the sound of the motors whether the functioning of the apparatus is good or bad. And should it be necessary to shut off the power, you all know of the mournful, gloomy silence following the sudden stop of all electric motors. The words "Shut down" which never mean much to the general public, but very alarming to the plant engineer or operator, is the expression ordinarily used in the case of motor stoppage.

The most common cause of a shut down is a sudden lack of power. It might also occur in the case of an imperfection in the mechanism of a pump or a motor. But in consequence of standby equipment installed in these plants to overcome such difficulties, the operator, after a short interruption, can continue the regular operations of the plant.

Now, what is there to say when one is compelled to turn off all pumps and shut out all motors of a pumping station, irrespective of perfect equipment and a good power supply? This is liable to occur even with plenty of water when the water refuses to enter the gravity intake pipe. That is nevertheless what happened at the Lachine pumping station on the first of January 1933, about one year after the completion of a new pumping station and filtration plant.

During twelve straight hours, that is from 2 o'clock a.m. till 2 o'clock p.m. on that day, the whole city of Lachine was without one drop of water.

The cause of such interruption, which we could not help, was the formation of frazil ice.

DIFFERENT TYPES OF ICE

There may be three different grades of ice in a lake or river: "Sheet Ice," "Frazil Ice" and "Anchor Ice."

* Presented before the Canadian Section, April, 1937.

Sheet ice is the ordinary surface ice. Frazil ice is that mass of ice separated from the surface ice, but laying between waters. Anchor ice, as its name implies, is ice which is found attached or anchored to the bottom of a river or stream.

It is a fact that if there should be formed a layer of sheet ice on the river, this would automatically remove all possibilities of formation of either frazil or anchor ice. Frazil ice, which resembles wet snow, is also often called slush ice, whereas anchor ice is more like crystals and its formation is more or less in lengths like needles. Quite often, there can exist both frazil and anchor ice at the same location.

The strength of the ice varies with the temperature, but the frazil and anchor ice will always be formed during the night and disappear slowly during the day under the power of the sunlight. Due to the action of the sun, the frazil and anchor ice rise to the surface and float away down with the current. After a cold night, when the sun rays shine early in the morning, the anchor rise will sometimes rise so quickly that we can see it two or three feet out of the water.

Frazil is formed in the water itself through wind or rapid agitation. Anchor ice may form on the bed of a river and may grow by attaching to itself frazil crystals carried by current. As frazil and anchor ice can only exist where there is no surface ice, we must take for granted that there must exist then, a rather strong current or river rapids, to prevent the formation of such surface ice. It is very often difficult to establish exactly the difference between frazil and anchor ice. The frazil is formed not only on the surface, but also throughout the body of the river where the water is super-cooled, and super-cooling is never more than a few thousandths of a degree.

INTAKE PIPE AT LACHINE STATION

The construction of the filtration plant of Lachine was started in 1931. The plant was set in operation on February 11th, 1932. There are no reservoirs. The capacity of the plant is 8,000,000 American gallons and is more than sufficient to provide for the needs of the population of 23,000 people in the city of Lachine and the town of Lasalle.

The intake pipe is of steel—3 feet in diameter and $\frac{3}{8}$ inch thick. The joints are of the "in and out" type, welded. The length of the intake pipe is 850 feet of which 765 feet is in the Lake St. Louis. Its depth is about 10 feet below the water surface.

The water enters the intake pipe by gravity, flows to a suction well

and is pumped by low-lift pumps to the coagulation and sedimentation reservoirs. A 36-inch valve is placed at the entrance of the suction well in front of the screen wells. Also, in possible case of frazil, an emergency opening with cover has been provided in the pipe at about 400 feet from the shore. The cover of the opening was to be removed in winter time only. The mouth piece of the intake is anchored in the bottom of the river by 4 concrete piers situated at distances varying from 25 feet to 50 feet.

Such were the conditions when the filtration plant was put in operation on February 11th, 1932.

FRAZIL TROUBLE

After the filtration plant was set in operation that day, everything went on perfectly well for a period of approximately one month. Suddenly, ice appeared in the intake pipe and threatened to block the screens in the suction well. Later an accumulation of ice close to the foot-valve stopped the water from entering the low-lift pumps. An emergency portable boiler was set up, and by means of steam, the ice was melted away. It seemed that both frazil and anchor ice found their way into the intake pipe. However, the anchor ice seemed to be what caused the most inconvenience in the suction well.

As the winter was ending, we could, with the use of the portable boiler, keep the filtration plant in full operation without any other interruption.

During the summer of 1932, we purchased and installed a high pressure "Marine Scotch" style, 32 HP boiler.

Special type of conduits are connected to that boiler which are attached to the screens of the suction well and to the three foot-valves of the low-lift pumps. A separate valve controls each of these conduits, directing the steam where necessary, when there is ice in the intake pipe.

We expected, that with this boiler, it would be quite possible to maintain free entrance of water into the filtration plant without any difficulty. But that was not sufficient, as will be seen by what happened during the following year.

THE SHUT DOWN

On that January day, from two o'clock in the morning until two o'clock in the afternoon, the water would not enter the suction well.

In a few minutes, the low-lift pumps of the pumping station had emptied both the suction well and the intake pipe. The latter became filled with air, the water having been pumped out of its whole length, and the middle section (about 300 feet long and curved) raised up to float on the surface of the river. The filtration plant as well as the pumping station were immobilized during twelve straight hours, and the water system of the City remained without a supply during all of that time. Around two o'clock in the afternon, the rays of the sun raised the frazil up to the surface of the water and it drifted down with the current.

The interruption was repeated on the 17th of January 1933, from five o'clock till ten o'clock a.m. Having foreseen this, we had organized with three portable pumps and one fire pump that were installed between the suction well and the shore of lake St. Louis, to pump the water from the river into the suction well. It was then 20 degrees below zero. The plans proved useless, as the water was freezing in the hose between the lake and the suction well.

INSTALLATION OF AN AUXILIARY PUMP

Later on, three projects were studied to overcome the inconvenience that might again be created by the frazil. Knowing that the frazil and the anchor ice could only be formed where there was no surface ice, the most simple and natural plan was to attempt to obtain surface ice over the top of the intake pipe for its whole length. Therefore, by erecting crib work above the intake pipe, it appeared that the surface ice would be protected against the current and the wind, and would consequently remain in its place all winter without breaking.

To illustrate this plan, it is necessary to point out the physical conditions adjacent to the filtration plant. The plant is constructed on the north side of lake St. Louis at about 100 feet up past Lachine wharf. The intake pipe runs in the river on a distance of 850 feet. Lake St. Louis is about 5 miles wide and the current is strong enough to prevent the formation of surface ice at the mouth of the intake pipe of the plant, in ordinary weather.

The ice mass that is formed on the lakeshore never covers up the portion of the pipe nearest the shore. When it is windy and very cold, the surface ice spreads over the river and covers the intake pipe completely. Should a southwestern wind rise, that ice breaks

away and leaves uncovered both the mouth and the emergency opening of the intake pipe.

We feel that the construction of a crib would have caused the ice to cover completely the intake pipe and thus prevent the formation of frazil both in 1933 and 1936 when so much difficulty occurred. But unfortunately, lake St. Louis at that very location being navigable, it became evident that this idea had to be abandoned in favor of a better project.

A second plan was then brought forward: the construction of another intake pipe in a location where surface ice would be formed and remain all winter. This plan will most likely be developed at a later date. At present it is deferred, owing to its extreme cost.

The third alternative that we have approved and executed is the installation of a low-lift pump. A 5 m.g.d. pump has been installed in the basement of the filtration plant a few feet from the suction well. A 16-inch water intake pipe was installed at about 50 feet from the shore at a spot where there can never be either frazil or anchor ice. The pump is connected directly to the suction well by means of a 12-inch outlet.

This installation produced the following results:

First, it supplies the water in sufficient quantity to satisfy the need of the low-lift pump; and

Second, it established a water head in the suction well with the ability to push back the water in the 36-inch main water intake by gravity, which will quite often clear away the blockage caused by the frazil at the mouth of the intake pipe.

Plans have been prepared to connect, when necessary, the auxiliary pump directly to the coagulation and sedimentation basins and avoid the use of the regular low-lift pumps when this unit is operating.

The installation of the auxiliary pump was made in the spring of the year 1933 at the cost of approximately $3000.

During the summer of 1933 we reinstalled into its place the 36-inch intake pipe that had lifted up from its bed to the river surface during the winter. We found out then that another displacement had occurred and another section was still 3′9″ higher up than its normal position on the river bed. We took advantage of these circumstances to install a few more supplementary concrete anchorages, and we have added a ninety degree elbow to the mouth-piece to do away with the water current and therefore obviate the free access at the anchor ice.

CONCLUSION

Since then, irrespective of the presence of frazil and anchor ice, the plant has always operated under normal conditions. On eleven occasions since its installation, the auxiliary pump has been operated. The shortest run was one and one half hours, the longest seventy-seven and one half hours. The total is 251 hours or ten and one half days of service, during which time the city of Lachine would have had no public water supply available if the installation had not been made.

RAISING WATER TEMPERATURE DURING SEVERE WINTER*

By Carl Leipold

(Superintendent, Water Filtration Plant, Winnetka, Illinois)

An inspection made at the Winnetka water filtration plant on February 20, 1936, showed ice thickness of 20 inches at the inlet and 22 inches at the outlet of the 15 foot depth open coagulating basins; 4 inches thick in the partially-enclosed concrete, rapid sand filters; and 7 inches thick at the outlet of the enclosed finished water reservoir. Freeze-up conditions on the distribution system also existed at the same period. To assist in overcoming the problems encountered during the unusually cold weather, the discharge from the adjoining municipal power plant condenser equipment was used for raising the temperature of the raw water supply at the water filtration plant.

The power plant condenser equipment (figure 1) used for a 2500-kilowatt turbo-generator, consists of a cooling pond with approximately 900,000 gallons capacity at 3½ feet average depth, 340 foot length by 100 foot and 132 foot widths; a recirculating pump, motor driven, centrifugal type, 5800 G.P.M. capacity, operating at 7.0 M.G.D. rate at period of raising temperature of raw water supply; and a surface condenser of 4700 square feet tube surface. The cooling pond is divided into two sections by a sheet piling wall having 3 sluice gates to by-pass the water from one section of the pond to the other for water temperature control. At the time of by-passing condenser water to the water plant intake, number 1 gate in cooling pond was wide open, number 2 gate was closed, and number 3 gate was wide open.

Raising the temperature of the raw water supply was done by opening the valves on the by-pass line from the condenser discharge line to the water plant intake pipe, and having the condenser discharge line valve (located at the cooling pond) in open position. The water flow under these circumstances is from the cooling pond

* Contributed record of operation.

to the condenser recirculating pump with discharge through the surface condenser and then to the cooling pond, a portion of the

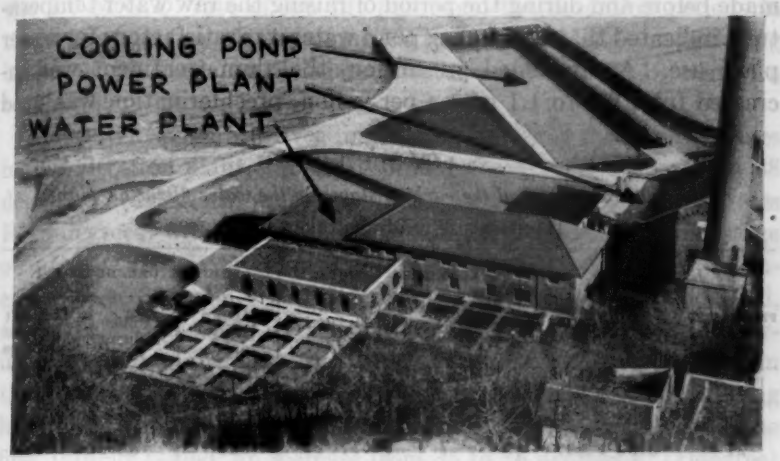

FIG. 1. AERIAL VIEW OF WATER AND ELECTRIC PLANTS

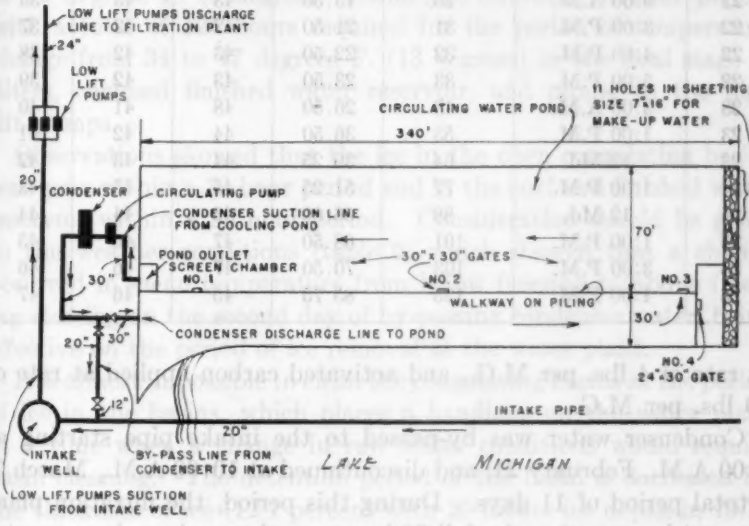

FIG. 2. POWER PLANT CONDENSER EQUIPMENT AND FILTRATION PLANT CONNECTIONS

condenser water by-passing to the water plant intake pipe. Make-up water for maintaining the proper water level in the cooling

pond was taken through the 11 openings in the sheet piling and also through gate number 4 (figure 2).

Daily laboratory analysis of the physical and sanitary qualities made before and during the period of raising the raw water temperature, indicated that the cooling pond water was satisfactory for water plant use. As an added precaution, the alum treatment was increased from 0.8 to 1.1 grains per gallon, prechlorination was used

TABLE 1

Temperature changes at the various stages in the water filtration plant

Temperature readings taken hourly

DATE, FEBRUARY	TIME	TOTAL PERIOD AFTER START OF BY-PASSING CONDENSER WATER, HOURS	TOTAL WATER PLANT SERVICE, HOURS	TEMPERATURE, DEGREES F.		
				Mixing basins, inlet	Filter influent	High lift pumps discharge
21	8:00 A.M.	Start	Start	32	33	34
21	9:00 A.M.	1	1	38	33	34
21	3:00 P.M.	7	7	46	38	34
21	4:00 P.M.	8	8	46	42	34
21	12 Md.	16	9.50	46	44	35
22	9:00 A.M.	25	15.50	43	43	36
22	3:00 P.M.	31	21.50	42	42	37
22	4:00 P.M.	32	22.50	43	42	38
22	5:00 P.M.	33	23.50	43	42	39
23	3:00 A.M.	43	26.50	48	41	40
23	1:00 P.M.	53	36.50	44	42	41
23	12 Md.	64	39.25	44	43	42
24	1:00 P.M.	77	51.25	45	45	43
24	12 Md.	88	56.00	46	44	44
25	1:00 P.M.	101	68.50	47	46	45
25	3:00 P.M.	103	70.50	47	46	46
26	1:00 P.M.	125	85.75	45	46	47

at rate of 4 lbs. per M.G., and activated carbon applied at rate of 20 lbs. per M.G.

Condenser water was by-passed to the intake pipe starting at 8:00 A.M., February 21, and discontinued at 10:00 A.M., March 3, a total period of 11 days. During this period, the filtration plant was not in operation the full 24 hours per day and condenser water was by-passed only at low lift pumps service period. The total service period for the low lift pumps was 180 hours and the condenser water by-pass period was 155 hours total. The 24 hour chart for the

intake well water level gauge, indicated that the rate of condenser water by-passed to the intake pipe varied between 35 to 80 percent of the 2.0 M.G.D. rate of pumpage to the filtration plant. At the 2.0 M.G.D. rate of low lift pumpage, the detention periods in the water filtration plant are: mixing basins—1.41 hours, coagulating basins—7.86 hours, and finished water reservoir—23.16 hours; a total of 32.5 hours.

The water temperature readings taken hourly at the various stages in the filtration plant (table 1), showed an increase from 32 to 38 degrees F. (6 degrees) within the first hour and from 38 to 46 degrees F. (8 degrees) within the following six hour period in the first stage of intake well, low lift pumps, and piping to filtration plant; an increase 33 to 38 degrees F. (5 degrees) within the first 7 hour period, an increase from 38 to 42 degrees F. (4 degrees) within the following hour, and an increase from 42 to 46 degrees F. (4 degrees) within the following 93 hours in the second stage of mixing and coagulating basins; an increase from 34 to 35 degrees F. (1 degree) within the first 16 hour period, an increase from 35 to 36 degrees F. (1 degree) within the following 9 hour period, and a gradual increase from 36 to 42 degrees F. (6 degrees) within the following 39-hour period, with a total of 125 hours required for the period of temperature change from 34 to 47 degrees F. (13 degrees) in the final stage of filters, enclosed finished water reservoir, and piping to the high lift pumps.

Observations showed that the ice in the open coagulating basins was gone within a 72 hour period and in the enclosed finished water reservoir within a 96 hour period. Consideration should be given to the weather conditions (table 2) which showed that a change occurred in mean temperature from below freezing to above freezing starting on the second day of by-passing condenser water, being effective on the period of ice removal at the water plant.

It is almost impossible to clean the coagulating basins at the period of ice in the basins, which places a handicap on the water plant at a time when a change in raw water conditions would require basin cleaning. The detention period of the basin is decreased by the thickness of ice (12.1 percent with 20 inches ice depth in 13.75 feet average basin depth) and by the increasing sludge depth (36.3 percent in the first 20 percent of basin capacity with 5 foot sludge depth in the same basin depth). Ice at the coagulating basin outlet weir decreases the area of the opening (81.5 percent with 22 inches

ice depth in 2.25 feet depth of outlet opening) with the weir located at the basin upper section and of a shallow depth design.

TABLE 2

Weather conditions and condenser water temperatures

Month of February, 1936

DATE	WEATHER			WATER TEMPERATURE AT CONDENSER, DEGREES F.			
	Temperature, degrees F.		Sunshine, number of hours	Inlet		Outlet	
	Mean	Minimum		Minimum	Maximum	Minimum	Maximum
1	6	−3	8.6	50	53	55	62
2	10	2	8.2	48	52	52	58
3	22	16	0	48	51	52	59
4	10	−5	10.1	43	51	48	59
5	−6	−13	10.2	47	58	50	65
6	6	−3	5.5	54	58	58	64
7	18	13	9.2	50	56	55	64
8	13	−7	1.2	48	58	54	66
9	−6	−10	10.0	51	56	55	64
10	4	−5	9.8	50	56	56	64
11	2	−6	10.4	48	54	53	62
12	12	6	1.4	48	52	53	60
13	26	19	0	46	53	51	60
14	15	0	6.1	47	52	52	58
15	4	−2	3.7	45	49	50	56
16	10	5	0.9	42	47	46	54
17	2	−6	0	44	51	48	60
18	−7	−14	10.8	46	54	51	62
19	1	−7	10.8	50	56	55	62
20	12	3	5.8	51	54	56	61
21	18	14	4.6	46	52	51	58
22	20	11	6.9	44	52	48	58
23	38	30	7.9	45	51	49	58
24	51	46	6.8	47	54	50	60
25	44	35	3.0	47	53	52	60
26	35	26	0.2	44	50	48	58
27	22	17	7.7	45	52	49	59
28	28	18	5.6	47	54	51	61
29	31	24	2.8	45	52	50	66

Weather conditions taken from Monthly Meteorological Summary, U. S. Dept. of Agriculture, Weather Bureau, Chicago, Ill.

Filter operations are affected by ice especially at the washing periods, as the ice piles up at the trough overflow plates and also

in the troughs, causing uneven distribution of wash water. Ice was removed from the four filters by first breaking the ice into small pieces with an axe before each washing operation, which permitted the larger portion of broken ice to be removed with the first flow of wash water and the remaining pieces of ice were washed into the troughs with a water hose and nozzle connection.

During the 9-year period (1922–1931) the jet type condensers for the power plant turbines, drew water from the intake well with discharge returned to the well. This operation increased the temperature of the raw water supply for the water plant and resulted in the absence of ice in the coagulating basins and filters, during the cold weather periods. Since the installation in year 1930 of the new turbo-generator with a surface condenser and cooling pond, condenser water is by-passed to the water plant raw water supply, only for emergency purposes.

Raising the temperature of the raw water supply at the water plant was done under the general direction of H. L. Woolhiser, village manager. The power plant equipment was controlled by L. Irgens, chief engineer of the power plant.

AERATION*

By Martin E. Flentje

(*Superintendent of Purification, Community Water Service Company, New York, N. Y.*)

Chemical engineers, in studying and investigating chemical plant procedures, have found their study simplified by dividing these processes into more or less standardized units of operation. These are known as "unit processes" or "unit operations." The production of potable water is essentially a chemical manufacturing process, such as storage, aeration, mixing, conditioning, sedimentation, filtration, and disinfection. The number of articles appearing in water works literature on these various subjects is proof that the investigation of these processes has not been neglected.

The unit process of water treatment known as aeration has also not been neglected. In the numerous articles describing it we find the names of many well known water works authorities, among them Drown, Hazen, Fuller, Whipple, Weston, Donaldson, Mahlie, Langelier, Baylis—to name but a few. Their reports contain sufficient information and data to answer many questions that may arise in the consideration of whether the inclusion or addition of aeration to our own water treatment plant would be the proper thing to do.

Certain information needs to be at hand before we can install aeration in our own treatment plant. Among the questions that would arise are the following:

(1) What can I expect aeration actually to accomplish in
   (a) the removal of odors?
   (b) the removal of the gases, CO_2, H_2S, and chlorine?
   (c) increasing the dissolved oxygen content of the water?
(2) What will I have to install to aerate my water supply properly?
(3) What will the operating costs be?
(4) Are there any other direct or indirect results of aeration which will be of advantage or of disadvantage to me?

* Presented before the Kentucky-Tennessee Section, March, 1936.

AERATION AND ITS POSSIBILITIES AND LIMITATIONS

Odor removal. Aeration may be defined as a process which exposes water to the air in some manner, usually either in the form of thin films, in sizable drops, or in a fine spray. It is an effective way of removing odors due to volatile materials or compounds that vaporize easily. The exposure of the water containing such materials in solution, in either bubbles or drops, to air sets up a "sweeping out" process which will remove a high percentage of the odors due to many algae, the odors due to the decomposition of dead algae after copper sulfate application, and the odors due to decomposition of organic matter in the stagnant water level of reservoirs. Aeration will not actually destroy more than a very few of the common algal forms. The fragile forms, Synura, Uroglena, Dinobryon, Anabaena, and Asterionella, may only be partially disintegrated during aeration. Odors due to industrial wastes and to phenols and cresols are not improved by aeration. This is also true of odors due to those compounds which, after chlorination, impart the familiar iodoform or medicinal taste and odor to water. Confirmation of these statements may be found in the reports of Hale (1), Mahlie (who at Fort Worth, Texas, found odor appearing when the dissolved oxygen content of the water decreased to about 80 percent of saturation), Spaulding (2) whose experience at Springfield, Illinois, was spray aeration gave varying results with good removal at times and little improvement at others, as measured by the Threshold Odor Method: and Flentje (3) in isolated tests at Greensburg where a reduction from 200 units to 57 was obtained through an Aer-O-Mix aerator. Experiments at Lexington, Kentucky, on a warm surface water gave an average of 25 percent cold odor removal over a riffle plate aerator (threshold odor measurements), whereas a simple up ended pipe with approximately 7 ft. fall at Apollo, Pa. gave little or no improvement on a surface water.

REMOVAL OF GASES

In the removal of any gas, as well as in any use of aeration, the efficiency of the process depends upon several factors. Whipple (4) states these as follows:

(1) The greater the concentration of the gas in the water and the smaller its volume in the air, the more rapid is its precipitation; or conversely—
The smaller the concentration of the gas in the water and

the greater its volume in the air the more rapid is its solution.

(2) The greater the surface of water exposed to the air in a unit of time the more effective are the absorption and sweeping-out processes.

(3) The greater within limits the change of air in contact with the water the faster does aeration proceed.

(4) The longer the time of aeration the more far reaching are the results.

The first principle means that aeration for removal of a gas is most efficient when the concentration of the gas is high in the water being treated and low in the atmosphere; and, that aeration to promote solution of a gas, as for instance oxygen to raise the dissolved oxygen content, is most rapid when the gas concentration of the water is low and that of the air high. Higher efficiency of aeration is obtained on a water having a CO_2 content of 50 p.p.m., than on a water with an initial content of 10 p.p.m. (2). The efficiency of aeration is also greater when the water surface is made as large as possible, explaining why it is desirable to have as fine a spray as possible.

Removal of CO_2. Free carbon dioxide gas can fairly readily be removed from water. In general spray aeration will remove 70 to 85 percent, and in some installations up to 90 percent of this gas. Temperature effects these results and efficiencies will be lower in winter than during the summer. One example is Waterford, N. Y., where a reduction of 84 percent was reported in August and but 60 percent reduction obtained in December. Other methods of aeration will usually not give as high reduction figures. Aeration through multiple coke trays can be made to approach spray aerator results, but generally coke trays are better adapted to waters where it is not necessary to get the highest efficiency. With loadings from 20 to 50 gallons per square foot per minute efficiencies from 50 to 80 percent can be obtained. Donaldson's (5) experimental results at Memphis are an example, (approximately 74 percent reduction). An aerator of this type recently installed at Cohasset, Mass., with loadings from 25 to 35 gal. per sq. ft. per min. gave an average efficiency of 57.5 percent in January 1936. Air used in air lift wells will give approximately 75 percent removal. Other types of gravity aerators are sometimes used, but usually do not give very high efficiencies. Whipple gives results on a "riffle" type at Cambridge, Mass. (indoors) on which CO_2 removals of 20 to 30 percent are obtained. A

similar aerator, but outdoors, at Lexington, Ky., averages approximately 45 percent removal during the summer. A cascade or step aerator at Portsmouth, Va., liberated about 40 percent of the CO_2. Perforated pans are slightly more efficient, but not as efficient as multiple coke trays, nor as efficient as a single deeper coke bed. Apparatus using the velocity of the water in an inspirator effect is used in the fairly recently developed Aer-O-Mix units. At Greensburg, Pa., in a raw water with low CO_2 content, with addition of alum to the throat of the Aer-O-Mix, usually either no reduction or a slight increase in the free CO_2 took place.

Removal of hydrogen sulfide gas. Hydrogen sulfide gas removal follows quite closely the removal of carbon dioxide. Hydrogen sulfide is less soluble than carbon dioxide and should therefore be more

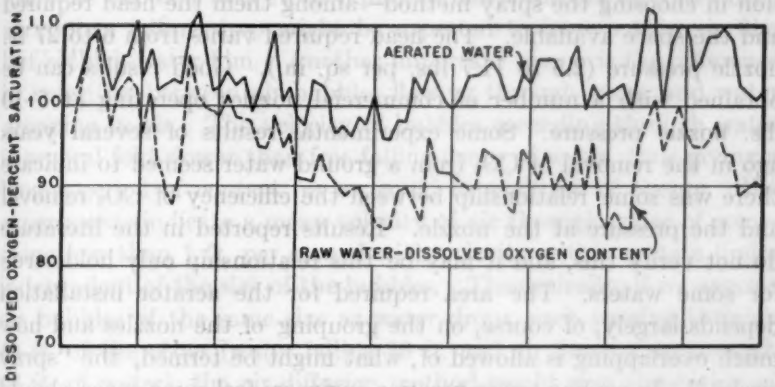

FIG. 1

easily removed. Another advantage is the usually lower concentration of this gas in water. Occasionally a water is encountered from which this gas is not readily removed by aeration in which it appears necessary to allow a time period for the liberation to go to completion. A water of this type containing fairly high concentrations of sodium salts has been encountered in Pennsylvania and from this water it has been extremely hard to get a finished water of no odor. To properly treat this water a good spray aerator is being installed followed by a period of detention of from 1 to 2 hours.

SOLUTION OF OXYGEN

A deficiency of dissolved oxygen is often encountered in water supplies, as for instance in stagnation layers in reservoirs and in

polluted streams. This condition is usually accompanied by disagreeable odors which can usually be at least partially removed by aeration. Bringing the dissolved oxygen up to saturation is a relatively easy matter and almost any type of aerator may be used. A graph is included giving some unpublished results on the increase in the dissolved oxygen through an Aer-O-Mix unit at Greensburg, Pa. (figure 1) This increase in dissolved oxygen content is necessary in the oxidation of dissolved iron for removal on filters.

AERATION APPARATUS

If installation of aeration is being considered, first choice of method would be probably given to spray aeration as available results indicate this to be the most efficient type. Several items need consideration in choosing the spray method—among them the head required and the space available. The head required varies from 6 to 27 ft. nozzle pressure (2.5 to 11.7 lbs. per sq. in.). Good results can be obtained with a number of commercial nozzles operating at 5–10 lbs. nozzle pressure. Some experimental results of several years ago in the removal of CO_2 from a ground water seemed to indicate there was some relationship between the efficiency of CO_2 removal and the pressure at the nozzle. Results reported in the literature do not verify this, and it may be this relationship only holds true for some waters. The area required for the aerator installation depends largely, of course, on the grouping of the nozzles and how much overlapping is allowed of, what might be termed, the "spray circles." In cooling tower practice engineers feel some space should be left between cones or spray areas to allow flow of air through and between the sprays. Whether or not this is desirable in aeration for water treatment is not known and does not seem to have been investigated. Quite likely it is possible to have the nozzles too close together, yet good results of aeration should be obtained in any new installation, if we follow the successful practice at other plants. The square feet of space allowed in several installations varies from 167 to as high as 1770 sq. ft. per m. g. per day. These figures, when figured to the area required for each nozzle used, varies from 12.5 to 177 sq. ft. per nozzle. The gallons per minute output per nozzle varied from 44 to 175 gallons. Almost any spray aerator will require protection from loss of water by wind carriage, which may also prove to be the source of complaints, if the installation is near houses

or buildings. This is usually prevented by a louvred fence around the spray pond, oftentimes made of wood.

AIR LIFT OR DIFFUSION

Aeration and the lifting of water from some wells is accomplished by the air lift method. This is a quite successful method, particularly in waters containing hydrogen sulfide. To get aeration it is, of course, necessary to allow time and space for the air and gases to escape. A very short period is required. The amount of air commonly used depends upon the distance the water must be lifted.

Aeration by diffusion should, according to Langelier (5), be a very efficient means of aeration. His reasons for this statement are that a fine bubble of air rising through a column of water would continuously be exposed to a fresh liquid surface, whereas in water drop aeration a falling drop might be expected to have a thin air film but a thick water film. Another important reason is the difference in velocities between air bubbles flowing through water and water dropping in air. The velocity of bubbles ascending through water is several fold slower than free falling drops of water, thus giving a longer period of contact for an equal expenditure of energy. His experiments indicate a mean velocity of air through water of something less than 1 ft. per second with velocity within certain limits independent of the size of the bubbles. Theoretically, if we assume air bubbles of the same size as water drops, each passing through 16 ft. of the other (water falling 16 ft. and air flowing up through 16 ft. of water), the air diffusion method would give absorption of 90 percent as against 15 percent, for the water drop or spray method of aeration. Air bubbles should be small and probably because a bubble increases to nearly 10 times its emergence size from the orifice, the orifice spacing should be at least 10 diameters apart to prevent coalescence. Porous plates and tubes, while not as yet in general use in water works practice, appear to be a very desirable development.

Aeration by air diffusion (by compressed air) has quite unusual opportunities in water treatment because it can so easily and quickly be tried out and used. This method has probably been overlooked as an easily applied emergency measure when taste and odor troubles appear. All that is required is an air compressor with approximately 5–10 pounds pressure (depending on depth of water) and a

perforated pipe system or a diffusor in the basin or reservoir where it is desirable to aerate. The perforated piping system need not be elaborate, and should usually not be put down over 15 ft. under water. The amount of air required is from 5300 cu. ft. per million gallons of water to be aerated to 160,000 cu. ft. per million gallons, or expressed more simply, from 0.005 cu. ft. to 0.16 cu. ft. of air per gallon of water aerated. These figures show a wide variation, but St. Paul reports very good results with the smaller figure in odor removal. The higher air requirements are recommended for CO_2 and H_2S removal. In this type of aeration a short period of detention is also recommended, being usually given as about 15 minutes. The power required varies considerably in the existing installations, but according to Roe may be estimated at an average of 1.0 kilowatt per m.g.d. capacity.

TABLE 1

Aeration Results—New Rochelle Reservoir

	DEPTH FROM SURFACE		
	27 feet (bottom)	13 feet	1 foot
Dissolved oxygen percent of saturation			
Before aeration	46.2	59.4	111.7
After aeration	84.5	89.8	86.8
Threshold odor			
Before aeration	5.0	1.7	1.33
After aeration	5.33	1.7	1.53

Tests after aerator running four hours and water passing over aerator at approximately 5 m.g.d. rate.

Roe gives the efficiency of this method of aeration as usually exceeding 75 percent with CO_2 removal and higher in the removal of H_2S. Some recent experimental results in an installation in a reservoir at New Rochelle, N. Y., using a Hytor Compressor of 35–40 cubic feet per minute capacity are shown in table 1. This installation was based on the air used at St. Paul, Minn.

PERFORATED PANS AND COKE TRAYS

The size of perforated pans may be patterned after successful installations at various points in the country. Usually the loading used is from 20 to 50 gallons per minute per square foot of area.

The essential thing is to get the proper distance of fall and not to get the perforations too large, the sizes being used being from $\frac{1}{4}$ inch to $\frac{3}{16}$ inch which may be placed one inch or so apart.

Pans with coke offer several advantages over empty perforated pans. Donaldson's Memphis experiments with the reported results at other locations show this type of aerator to be quite adaptable and quite economical, using very little head. In iron removal this type of contact is of especial benefit. Approximately the same loadings as for perforated pans should be used. Donaldson's experiments show a flattening of the efficiency curve at and beyond approximately 45 gallons per minute (per square foot); that is below 45 gallons per minute higher efficiency of CO_2 removal is obtained, whereas above 45 gallons per minute the efficiency stays almost constant without, however, much falling off of efficiency. Experience with this type of aerator indicates not much higher rates than 35 gallons per square foot should be used. Three to four trays should be used and from 8 to 12 inches of coke from possibly $\frac{1}{2}$ to 2 inches in size. The pans should be from 8 inches to 15 inches apart. Louvres, or some other protection to prevent loss by winds, are necessary.

Cascades or falls over steps should be designed to give as thin a film of water as follows.

The size of Riffle type aerators may be designed to give flows of 10 to 20 gallons per minute per square foot of area with the apron sloping somewhere near 1 foot on 2 or 3.

Up-ended pipes are probably the simplest type of aerator and can be used to use up any available head. To get the maximum benefit the fall should be for as long a distance as possible, and possibly aided with splash pans for additional breaking up of the water.

Little data can be given for space and head requirements for such aerators as the Aer-O-Mix, which are self contained units. These require approximately 8 feet head to operate successfully by gravity, although lower heads can be used if additional air is provided by means of blowers. This type of aerator is well adapted to certain plant conditions and does not require much space nor any protection from wind.

ADDITIONAL BENEFITS AND RESULTS OF AERATION

No specific mention has been made of the need for aeration in iron and sometimes manganese removal. Aeration of this type re-

quires the absorption of oxygen for oxidation of the iron or manganese, and is usually quite easily accomplished. On some waters aeration not only supplies the oxygen required, but also raises the pH through removal of CO_2, which appears necessary to make the iron precipitate out on the filters.

One disadvantage of aeration is its effect on the dissolved oxygen content. A well water often has a very low dissolved oxygen content, and unless the pH is quite low, this lack of dissolved oxygen should result in a lowered rate of corrosion. From the standpoint of corrosion the increase in oxygen is a disadvantage. Another disadvantage is the exposure to air, dust and sunlight. This may promote algae growths in any type of aeration out of doors.

SUMMARY

A resume of the various types of aerators available has been made and some idea given of the efficiency that may be expected from these various types for removal of the gases common to water supplies, for the absorption of oxygen and the removal of odors. Some idea has been also given of the type of apparatus that can be used and the amount of space required.

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SAFETY FIRST IN WATER PLANT OPERATION*

By Chris F. Bingham

(*Chem. Engr., The Columbia Alkali Corporation, New York*)

The health and safety from injuries and death of employees is a matter of humanitarian, technical and economic interest. Despite the fact that safety conditions in the field have been greatly improved in recent years, there is still, and always will be a real need for further reduction, and if possible, the elimination of all hazards in the industry.

Before considering the hazards peculiar to water works, the particular field under discussion, it must be emphasized that to properly evaluate any hazard, one must, first of all, know what sort of man it is the hazard threatens.

In the average water works plant the labor turnover is small and it is generally accepted that a small labor turnover is a distinct advantage over a large one. The safety program can be developed over a long range and education becomes of a progressive nature and the ground gained is very rarely lost.

A water plant also has the advantage that the man at the top of the safety program is also the head of the plant organization. He can make personal contacts with all of his employees which, in itself, is a factor absolutely necessary for perfect coöperation for a safety program.

Most accidents arise from three main sources within the individual —carelessness, ignorance, or improper methods. If these three factors are corrected 98 percent of our accidents in all industries would be eliminated. Training is absolutely essential in safety, the same as training for operation. In fact, if a person learns to do an operation correctly, he will automatically learn to do it in the safe way. It is just as easy to do it, usually a great deal easier, in the safe than in an unsafe manner. If a man is careless in his work, his reliability as a "guardian of health" is not dependable and the best procedure is to replace him. We must always consider the

*Presented before the North Carolina section, October, 1936.

operator of any water plant the leading safety man of the community and try to imagine what would happen if, due to his carelessness, an unsafe water was delivered to the community for a short period of time.

Safety in waterworks resolves then itself into knowing how to work, knowing how to use the tools of the industry and having a perfect understanding of the physical and chemical properties of any of the hazardous chemicals involved.

The hazards peculiar to water works plants include many of the ordinary hazards of industry.

The handling of heavy materials such as pumps should be carefully watched. The use of chain and rope falls is standard and well covered in standard literature. Inventories should be made of all machines having moving parts exposed and a routine inspection established that will insure against accidents arising from mechanical failure.

It should be an unalterably established practice that nothing whatever should be supported by tackle of any kind, only so long as it is being raised, or lowered, or, as in the case of falls on an overhead trolley, while being moved laterally. At all other times, materials should be fully supported by horses or blocks.

Switch gear equipment should be thoroughly protected by suitable enclosures to prevent bodily contact with the system. Manually operated starting switches around pumps should be located so that the operator stands in a clean dry area in starting the pump. If this is impossible, a small insulated platform should be made so that the operator must stand on it in order to operate the starter.

The use of danger signs around the area ways or ladders is to be commended. Modern water plants are now laid out with a great deal more accessibility for the operator than ever before. Some plants still have deep pump pits completely unprotected by even a railing. The attitude there taken is that no one but the operator goes in that particular area, but nevertheless some day that one man will forget.

Railings should be provided around basins and, if only one operator is on duty, a very low railing should be provided in case that he should slip or fall he will not roll over in the basin. In plants having only one operator some companies have found it excellent practice to have the operator report to some central station at least once hourly.

Elevators should be provided with safety gates, those operating automatically are to be preferred. In modern passenger elevators this is one of the requirements of construction. However, many plants have installed freight elevators, usually for handling the chemicals, which contain no such safety features at all.

CHEMICAL HANDLING AND STORING

Perhaps the greatest hazard presented to the water works operator is in the handling, storage and use of the chemical used in the water purification process. Activated carbon should not be stored in close proximity to quicklime or bleaching powder. It should also be stored in thoroughly dry places with ample air circulation. Carbon which has been wetted and is drying out in a space devoid of air circulation is a potential fire hazard.

Likewise lime should not be stored near activated carbon and quicklime should be stored in such a manner as to provide good air circulation about it. In handling lime, or any chemical, for that matter, into dry food machines, sufficient dust removal facilities should be provided so that it will not be obnoxious to the operator.

The compressed gases perhaps present the greatest hazard in the water purification plant of any of the chemicals used. A great deal has been written about the safe use of chlorine and of ammonia both by the industry and independent committees and is available to all operators.

The Committee on Chemical Hazards in Water Works of the A. W. W. A. completed in 1935 an excellent report on chlorine and in 1936 another report on ammonia. Both of these reports were written in a form that is strictly educational bearing on the assumption that any man having a thorough knowledge of the chemical and physical properties of chlorine and ammonia and a thorough knowledge and understanding of the containers they are shipped in will be fitted to handle these chemicals safely—not because of certain written "Don'ts" but because he will understand why these don'ts have been set forth. Much has been written about the need for having a gas mask as a safety feature. Fortunately, but perhaps unfortunately too, the fact is that these masks are not required to be brought in use often. Differing with others on the subject, the author believes that the canisters on these gas masks do depreciate over a period of time and one of the best methods of determining this is by an occasional use in a very weak concentration of chlorine or am-

monia. There is also the fact that many plants have gas masks, but many of these same plants do not have all of their men thoroughly trained in the putting on of the mask and in being able to do light work with the mask on. Gas mask drill or instruction in the use and wearing of the gas mask is just as important as having one at the plant.

There remains only one point of general safety not covered as yet by this paper—that of Fire Prevention. Your local fire department will coöperate with you in inspecting your properties and making suggestions. The idea of a waterworks burning down sounds absolutely ridiculous but we should stop and take an inventory of how many of our plants containing flamable materials, electrical equipment, etc., have adequate five extinguishers which are in proper order.

COMPARATIVE PHYSICAL DATA OF TRANSITE AND CAST IRON PIPE*

Pursuant to a resolution adopted by the American Water Works Association in convention at Buffalo, June 7, 1937, the Committee on Waterworks Practice has summarized the comparative physical test data relating to Class B Cast Iron Pipe and Class 150 Transite Pipe which were presented in discussion of a first progress report of the Sub Committee 7-T printed in the May 1937 issue of the JOURNAL.

Physical test results of Class 150 transite pipe (Underwriters Tests) and of A. W. W. A. (Specifications of 1908) Class B cast iron pipe (A. S. A. Tests)

	BURSTING TEST	RING CRUSHING TEST	BEAM TEST	
			Load at failure	Deflection
	lbs. per sq. in.	*pounds*	*pounds*	*inches*
6″ Transite	852	5,197	2,030	0.732
Cast Iron	2,270	19,870	22,100	1.56
12″ Transite	739	5,564	No comparable data	
Cast Iron	1,476	16,730	Data available	
20″ Transite	654	10,315	No comparable data	
Cast Iron	1,120	13,400	Data available	

The test data for Transite Pipe are taken from results of tests made by the Underwriters Laboratory of Chicago, Illinois, for the manufacturers, and all values were calculated to standard wall thickness using minimum thickness at break. Printed copies of report are available from Johns-Manville Products Corporation and Underwriters Laboratories, Inc.

The test data for Class B American Water Works Association Specifications Cast Iron Pipe are taken from the results of tests made by the University of Illinois and Iowa State College, for Committee A-21 of the American Standards Association for Specifications for Cast Iron Pipe of which the American Water Works Association is a

* Presented in accordance with resolution adopted June 7, 1935, in meeting at General Convention.

sponsor body. Unpublished test data from American Standards Association Committee A-21 are on file in A.W.W.A. headquarters.

The preceding table shows the average results of full length bursting, ring crushing and beam tests of Class 150 Transite and A. W. W. A. Class B Cast Iron Pipe.

The Committee on Water Works Practice takes this opportunity to emphasize the fact that the report of Committee 7-T on Transite Pipe was in large part a quotation of the general conclusions of the report of the Underwriters Laboratories, Inc.; that it was a progress report made to invoke discussion; and that it did not indicate in any way action or recommendation of the Committee on Transite Pipe.

MALCOLM PIRNIE,
Chairman Committee on Water Works Practice.

June 10, 1937.

ABSTRACTS OF WATER WORKS LITERATURE

Key: JOURNAL of the American Water Works Association, 29: 10 (1937). The figure 29 refers to the volume, 10 to the page of the JOURNAL and (1937) to the year of issue.

WATER SUPPLY ADMINISTRATION

Air-Conditioning. What it Means to the Water Utility. L. L. LEWIS AND L. H. POLDERMAN. W. Wks. and Sew., 83: 335 (1936). Winter water demand of air conditioning equipment is small and summer refrigerating load is of greatest concern to water works man. There are three types of cooler: (a) water alone, (b) the cooling tower, and (c) the evaporative condenser. Choice of type depends on water cost, and on capital available, for construction cost varies inversely with water use. Procedure for calculating possible load is shown. Without cooling tower or evaporator, maximum demand is 15 gallons per person served per day. In January 1936, about 1.27 per cent of urban population of U. S. was served with air-conditioning, resulting in a peak water demand of 1.65 gallons per capita daily. It is expected this figure will double annually for several years. Danger of excessive loading on certain water mains may result where there is a concentration of equipment, and some now adequate supplies will need augmenting to accommodate the new air-conditioning load.—*H. E. Hudson, Jr.*

Operating results of St. Paul Water System. Eng. News-Rec. 117: 367 (1936). Brief data given from annual report for 1935. Consumption averaged 76.2 gallons per capita, or 354 gallons per tap, to total of 292,000 people served, including South Saint Paul and West Saint Paul. City is 99.9 per cent metered. Domestic consumption is 56 and commercial use 44 per cent of total. Consumption on maximum day, July 30, was twice the average. Population of Saint Paul is 485 per mile of water mains and total area 55.44 square miles. Costs per million gallons were: administration and general, $17.83; production, $12.63; distribution $21.53; fixed charges, $56.55; total, $108.54. Revenue per million gallons was $117.10. In production item, filtration accounted for $6.35, compared with $6.93 in 1934. Filter washing required 2.53 per cent of water pumped. Filter runs averaged 44 hours. Chemicals used were as follows: alum, 0.81 grain per gallon; chlorine, 0.75 p.p.m.; ammonia, 0.16 p.p.m. Chemical cost was $1.98 per million gallons. Turbidity of influent was 5 p.p.m. and of effluent nil. Average of 666 bacteria per c.c. in influent was reduced to 7 in effluent. B. coli index was reduced from 8.51 to 0.—*R. E. Thompson.*

Cutting Legal Tangles to Get a Water Supply. FRANK D. PETERSON. Am. City 52: 67 (1937). Surface contamination of their wells compelled the neighboring boroughs of Collegeville and Trappe, Pennsylvania to install a new

water supply system. The laws and court decisions of Pennsylvania indicated that a joint water-works system would be impossible. Accordingly, only the PWA financed water-pumping plant was built and operated jointly, while the distribution systems were built and owned by the respective boroughs. Water is pumped from two wells to a clear basin where it is chlorinated and from which it is pumped to an elevated tank.—*Arthur P. Miller.*

Customer Accounting Practice for a Municipal Water Works. HAL. F. SMITH. Eng. Con. Rec., **50**: 1088 (1936). Practice in Detroit, Michigan, which is described in some detail, is influenced to considerable extent by fact that city charter bestows on water department right of lien as security for charges for water service. There are 274,000 customer accounts, services being practically 100 per cent metered. All accounts are billed quarterly except those with meters 4 inches or larger, which are billed monthly. Cycle billing, which assures even flow of work and absence of peaks, is practised. Accounting system employed is combination bill and ledger plan, using public utility billing machines. Sequence of operations is outlined and principal forms used are illustrated.—*R. E. Thompson.*

Comparative Fire-Protection Value of Distribution Systems. CHARLES H. CAPEN. W. W. Wks. and Sew., **93**: 356 (1936). The quantity and size of water mains and hydrants in relation to population and area served determine the effectiveness of a system for fire-protection. Inch-square-foot units are preferred to inch-foot units in evaluating effectiveness. Four plottings of per-capita distribution facilities against population density are given. From studies of these, an equitable schedule for fire-protection charges is established.—*H. E. Hudson, Jr.*

Changing a Town from Flat Rates to Metered Rates. DWIGHT L. AGNEW. Jour. New Eng. W. W. Assoc., **50**: 340 (1936). The high percentage of summer houses (24 per cent) in the Hingham Water Co. territory presented an unusual problem when metering was instituted. In 1935, 1168 meters were set in the summer houses, 869 removed, 2259 houses shut off and 1953 turned on. Metering of one section of territory was started in 1935 by company's own crew, avg. cost of installation without meter $4.38, in many installations in which conditions were ideal cost was only $1.72 for material, labor and trucking. For ease in setting and removing and small space required, copperhorn setting was used. —*Martin E. Flentje.*

A Load Factor Water Rate. W. A. KUNIGK. Eng. News-Rec., **116**: 775 (1936). Brief details are given of new sliding-scale rates being established in Tacoma, Washington, for large consumers using not less than 1 m.g.d. per month (pulp mills), employing load or demand factor as is practice in distribution of electrical energy. Rate is based on monthly maximum demand in cubic feet per second, which is taken as average rate of consumption in four 30-minute periods of peak demand, taken at intervals at least 3 hours apart, as shown by recording chart. For this class of service, venturi meters are used and flow is shown on recording charts and totalizers. Charge per 100 cubic

feet will begin at 1.5 cent for the first 1 million cubic feet for each second-foot of monthly maximum demand and range downward to 0.5 cent. As 1 second-foot is equal to 2,590,000 cubic feet per month, minimum consumption of 1 m.g.d. (approximately 4 million cubic feet per month) will be about 1.58 second-feet. Minimum monthly bill would be about $431.45, which is $14.38 per m.g., or 1.08 cent per 100 cubic feet.—*R. E. Thompson.*

Price Set for Aqueduct Water. Eng. News-Rec., 117: 486 (1936). Board of Directors of Metropolitan Water District of Southern California has stated that rate of $15 per acre-feet (3.45 cents per 100 cubic feet) will be charged for Colorado River aqueduct water delivered to cities and areas within district. Average rate paid for all domestic, commercial, and industrial water now retailed in 13 district cities is 12 cents per 100 cubic feet. Aqueduct water will be made available only to cities within district. Construction is now almost half completed and delivery is expected in 1939.—*R. E. Thompson.*

A Comparison of Water Bills in Various Cities. Eng. Cont. Rec., 50: Jan. 13, 25 (1937). Data compiled for Water Works Information Exchange of Canadian Section, American Water Works Association, are given showing water charges in various municipalities in Canada. Charges are divided into 2 sections: (1) flat basis, (2) metered basis.—*R. E. Thompson.*

A Comparison of Water Rates in Representative Canadian Municipalities. Eng. Cont. Rec., 50: Feb. 10, 21 (1937). Data from same source as that given in previous abstract are presented regarding rates charged outside municipal boundaries.—*R. E. Thompson.*

Upper Rio Grande Problem Under Study. Eng. News-Rec., 117: 331 (1936). In attempt to put an end to long-continued controversy between Colorado, New Mexico, and Texas over equitable diversion of waters of upper Rio Grande River (above Fort Quitman, Texas), engineering investigation of water resources and needs of area is now in progress by cooperative action between 3 states, various federal bureaus, and National Resources Committee. It is known as Rio Grande Joint Investigation. Essential problem is determination for upper Rio Grande basin and for each of 3 major use areas (San Luis Valley, Middle Rio Grande Valley, and valley below Elephant Butte) of (1) water supply, (2) water requirements, (3) possibilities of adding to water supply by storage, importation (transmountain diversions), and salvage of present wastes and losses. This involves measurement of stream flow, of diversions and wastes, and of consumptive use; mapping of vegetative cover; survey of reservoir and dam sites; study of transmountain diversion projects; and survey of underground water resources.—*R. E. Thompson.*

New Water Supply System in Exeter, Ont. D. H. FLEMING. Eng. Cont. Rec., 50: Feb. 10, 9 (1937). Original water works system of Exeter, village of 1600 population, derived supply from Ausable River, a highly polluted stream unsuitable for domestic use. Recently, new 200,000-g.p.d. supply has been developed from Frayne springs by laying collecting system of perforated tile

with open joints at depth of 10 feet below ground surface. Automatically controlled low and high pressure pumps, operating alternately according to demand conditions, deliver water through single 6-inch line to distribution system and elevated tank which rides on system or to 250,000-gallon subsurface reservoir. Details of control equipment, designed to draw water from springs to limit of their capacity at all times, is included.—*R. E. Thompson.*

New Small Filtration Plant Gives Complete Treatment. ANON. Am. City, **52**: 81 (1937). With PWA financial assistance St. Elmo, Illinois completed repairing certain old water supply facilities and a new filtration plant. The existing impounding reservoir was enlarged by the use of wooden flash-boards to increase water depth by 24″; the dam was strengthened by rip-rapping the inner slope and placing additional fill and the spillway doubled in width to more adequately handle flood flows. The new treatment plant includes chemical apparatus, a pre-mixer for use before an Infilco Super-Mix, a sedimentation basin of 3½ hour settling capacity and 2 rapid sand filters with Transite pipe manifolds and laterals. Wagner underdrain blocks with slots were placed between each pair of laterals.—*Arthur P. Miller.*

Domestic Water Consumption in a Large Constructing Camp. Eng. News-Rec., **117**: 364 (1936). Brief data given regarding water consumption in government and contractor's camps on Grand Coulee Dam project on Columbia River. Populations are 525 and 2,500, respectively. In government camp, consumption during typical summer month was 49.5 gallons per capita per day from potable water system and 224 from auxiliary fire protection and lawn sprinkling system, total of 275. In Mason City, contractor's camp, consumption is about 265 gallons per capita per day.—*R. E. Thompson.*

The Shanghai Waterworks Co., Ltd., annual report for 1935. C. D. PEARSON. 53 pp. (1936). Operating data are given in tabular and graphical form. The av. consumption was 46.12 million gallons per day or 20.35 gallons per capita. The latter figure has been reduced 33⅓ percent by complete metering. The amt. of alum used averaged 1.125 grains per gallon. The water applied to the rapid sand filters, which are operated at the rate of 100 gallons per sq. ft. per hr., is prechlorinated, the av. dosage being 1.043 p.p.m. Cl, in smaller amts., is also applied later in the purification process. The wash water used averaged 2.77 percent of the filtered water. The av. rate of filtration through the slow sand filters was 1.68 gallons per sq. ft. per hr. and the av. length of run between cleanings 16.62 days. The percentages of positive B. coli tests in the various dilns. of the treated water were as follows: 100 c.c., 6.1; 10 c.c., 1.8; 1 c.c., 0.2; 0.1 c.c., 0.2. The gross revenue averaged 40.1¢ per 1000 gallons.—*R. E. Thompson.*

Water Works Emergencies. W. J. SCOTT. Health Bull., **50**: 300 (1936). From a health standpoint, water works emergencies may be divided into two groups: (1) shortages of water where the normal public water supply fails or threatens to fail, and (2) pollution of the public water supply due to some abnormal occurrence. Several instances are given of emergencies of both types

in Conn. during the recent past. In all emergencies the health authorities stand ready to coöperate with water officials in taking all necessary steps to safeguard the public water supply and the public health.—*G. C. Houser.*

HYDRAULICS

New Functions for the Hydraulic Laboratory. GEORGE E. BARNES. W. Wks. and Sew., **83**: 360 (1936). The modern hydraulics laboratory requires a flexible set-up. The equipment at Case School of Applied Sciences, Cleveland, O., is described. With it tests were conducted for the Muskingum watershed project and for numerous sewage works. Model tests have great value in advance of construction, in providing best operating design and greatest economy. Model tests can be carefully checked by full scale tests after construction and the former prove very reliable.—*H. E. Hudson Jr.*

Flow Turbulence Analyzed by Means of Photography. Eng. News-Rec., **117**: 684 (1936). In study of loss of head in cast iron tees made at Texas A. and M. College and reported in Bulletin 41, photography was effectively employed as aid in checking experimental data and conclusions regarding lines of flow and turbulence. Glass tee was substituted for cast iron tee in piping system and to make stream-line visible, small bubbles of hydrogen and oxygen were produced electrolytically in water, which had been acidulated with sulfuric acid. Illustrations given showing flow lines and eddy currents when 50 and 100 percent of flow is diverted at right angles.—*R. E. Thompson.*

A Formula for the Adjustment of Current Velocity Meters. OTTO RACKER. Eng. News-Rec., **117**: 327 (1936). Assumption that electric velocity meters are accurate to about 3 percent is true only if friction on bearing of vertical spindle is same as when rating table was made. Friction does not remain constant and readings may vary considerably. Results obtained varying by as much as 12 percent from 2 instruments of same type and manufacture, apparently in good working condition, and having identical rating tables. To obtain accurate readings, necessary to adjust instrument periodically by setting spindle at same friction as it had originally. Formula for making such adjustments given.—*R. E. Thompson.*

Discharge Characteristics of the Free Overfall. HUNTER ROUSE. Civ. Eng., **6**: 257 (1936). Many attempts have been made to apply the principle of critical depth of parallel flow to measurement of flowing water. No particular success has been achieved and all devices using this principle require careful rating. Author shows the possibility of using free overfall as a flow meter needing no calibration. By theoretical means a value for the contraction coefficient (0.715) is established which numerous measurements have shown to be equal to the ratio between crest depth and computed critical depth, regardless of rate of discharge or channel width. The crest section in a free overfall is the true section of minimum energy and as such is a suitable control point at which a single measurement should permit a simple and direct detn. of the rate of discharge. Recent investigations bear out this promise and author concludes

that while further large scale expts. are in order, the use of the crest section as the control point for measurement of discharge will not only further search for a satisfactory critical depth meter but will also provide a simple and dependable method of detng. discharge in rectangular channels that end in a free overfall.—*Martin E. Flentje.*

A Portable Hydraulic Laboratory. Scott B. Lilly. Civ. Eng., **6**: 241 (1936). Description of an ingenious portable hydraulic apparatus by which characteristics of various weirs, orifices etc. may be readily shown to students. Flumes and tower of celluloid permit visual examination and in some cases measurement. Apparatus consists of small tower, flume, storage tank and pump with arrangements for inserting various types of weirs, varying the flow, head, etc. Photographs illustrate points brought out and indicate the usefulness of this $350 apparatus.—*Martin E. Flentje.*

POWER AND PUMPS

Combustion Qualities of Diesel Fuel. G. D. Boerlage and J. J. Broeze. Ind. Eng. Chem., **28**: 1229 (1936). Physical delay (endothermic) and chemical delay (exothermic) occur in ignition period. For normal light diesel fuels, chemical character governs ignition. After-burning is largely due to uneven distribution and to slow evaporation of fuel deposits from combustion chamber walls. Mixing is influenced by viscosity, volatility, and ignition quality of fuel. A better volatility scale for diesel fuels is needed. Experiments with light and heavy fuels are described. From study of after-burning and unburned products it is concluded that combustion in compression ignition engines is mostly of the destructive type, though probably partially oxidation under certain conditions.—*Selma Gottlieb.*

Another Diesel-Generator for Kitchener Water Works. Eng. Cont. Rec., **50**: 841 (1936). Five years ago, diesel generator unit, rated 500 hp., 375 kv.a., was installed in Schumaker Ave. pumping station. In June last, similar unit was installed in Strange St. pumping station for same purpose as other unit, *i.e.*, peak load and emergency use. New installation consists of 300 hp., solid injection, 6 cylinder, 375 r.p.m., diesel engine, direct connected to 112 kv.a., 25 cycle, 2200 volt generator.—*R. E. Thompson.*

Developing High Efficiencies in Large Single-Stage Pumps. J. M. Gaylord. Eng. News-Rec., **118**: 45 (1937). Flood waters of Colorado river are to be stored in Boulder reservoir, released as required and allowed to flow down natural river channel about 150 miles to Metropolitan Water District aqueduct intake at Parker dam. Water must be lifted total of 1,616 feet at 5 pumping plants located at advantageous points along 242-mile aqueduct. From last pump lift, 126 miles from intake, water will flow by gravity remaining 116 miles to Cajalco reservoir, from which 150 miles of feeders in distribution system can be served by gravity. Locations and heights of pumping lifts were fixed largely by topography of route selected. When ultimate capacity of aqueduct is being delivered, which is not expected for considerable time, pumping re-

quirement will be 300,000 kilowatts and annual energy consumption 2.5 million kilowatt-hours. Total cost of $33,000,000 for pumping system and annual operating expense exceeding $5,500,000 presented problem in pump design worthy of most careful consideration. Drop in efficiency of 1 percent would increase operating costs about $50,000 per annum; thus value of saving 1 percent in efficiency can be capitalized at $1,250,000. Entire aqueduct design, including pumps, is based upon district's right to 1,100,000 acre-feet per year, equivalent to continuous flow of 1,500 second-feet. Allowing 7 per cent outage time, system was designed for 1,605 second-feet. Capacity at each pumping plant is to be subdivided into 9 units, including 1 spare, all of 200 second-feet capacity. Horsepower capacity of motors will be 4,300 for low head, 9,000 for medium and 12,500 for high head pumps. Numerous estimates indicated clearly that construction costs would be greatly reduced by adopting vertical-shaft pump and this type was selected. Extensive tests have been conducted in laboratory built for purpose at California Institute of Technology. Equipment permits determination of pump efficiency with precision well within 0.1 per cent. Several hundred model tests were made. No definite difference in operating characteristics of single and double suction type pumps was found and former was selected owing to simpler station design resulting from its use in vertical shaft form. Use of single-stage pumps for 452-foot lift at Eagle Mountain and 476-foot (maximum) lift at Hayfield offered definite saving of several hundred thousand dollars in first cost of these plants This is radical step in design of large centrifugal pumps, previous maximum being less than 300 feet. No material sacrifice in efficiency was discovered. Speeds adopted vary from 300 to 450 r.p.m., minimum positive inlet pressure head of 5 feet being found correct for good operation and freedom from cavitation. Transient conditions on starting and stopping pumps, particularly during sudden shutdowns due to power failures, were thoroughly investigated. Immediate saving in construction cost as result of tests is conservatively estimated at $750,000, many times cost of work. Additional savings will accrue as plants are completed and better operation and sustained efficiency is expected to result. Contracts were awarded to 3 manufacturers and each has submitted for test model representing pumps to be furnished. All show efficiencies of approximately 91.5 per cent. Materially higher efficiencies are to be expected in full-size units. Initial installations, three 200 second-feet pumps at each plant, are now under way. Additional units will be installed as demand increases.—*R. E. Thompson.*

Screw and Propeller Pumps Meet With Favor on European Works. C. H. S. TUPHOLME. W. Wks. and Sew., 83: 354 (1936). Article describes open and closed types of vertical propellor pumps which are being used widely for low head pumping in Europe. These run at high speeds and are 70 to 83 per cent efficient.—*H. E. Hudson, Jr.*

Chicago's New Cermak Pumping Station. L. D. GAYTON. W. Wks. and Sew., 83: 365 (1936). The all-electric, 300 MGD., Cermak Station replaces three obsolete, expensively operated, stations. Plant is described and illustrated. Overall pump and motor efficiencies exceed 88.5 per cent. Plant is

flood-proof and fire-proof. Plant costs and chlorinating equipment are mentioned.—*H. E. Hudson Jr.*

Experiences with Automatic Control Equipment at Pumping Plants. H. A. HARRIS JR. W. Wks. and Sew., 83: 269 (1936). California Water Service Co. operates 140 pumping stations, of which 137 are electric, 3 steam. For economy and satisfactory operation of electric plants, three types of automatic controls are used widely:—(1) float switch, (2) pressure control, and (3) time clock. Various installations are described, with particular detail devoted to surge trouble elimination. 104 of the pumping plants are automatically controlled. Cost of labor totals $4.35 per MG. and labor cost per station is $440 annually. There are 267 pumping units and maintainance cost is $28 per year each.—*H. E. Hudson Jr.*

Automatic Control of Pumps for Railway Water Tanks. J. E. HAWE. Rway. Elec. Eng., Sept. (1936). A trouble free automatic control system for motor driven pumps at railway water stations has been difficult to obtain, especially where severe cold weather is encountered. Dependability is the first essential requirement. Float control systems cannot be used advantageously. The Great Northern Railway installed at Interbay, Wash., a pressure-control system with a thermal-type snubber effecting the time-delay in actuating the switch controls which appears to have successfully eliminated the trouble experienced from starting and stopping surges. Oil chambers are recommended where trouble is encountered with freezing in the copper tube connecting line from the pressure unit to the pump discharge line.—*R. C. Bardwell.*

Gravity Pressure to High District with New Steel Tank. ANON. Am. City, 52: 72 (1937). At Augusta, Georgia the water distribution system naturally falls into three districts; the low and intermediate served by gravity and the high served by booster pumps. Inadequate storage capacity in the high district made necessary a new 500,000-gallon elevated tank of colonial design adjacent to the sedimentation reservoirs. The new tank has tubular columns, a radial cone bottom and an ellipsoidal roof.—*Arthur P. Miller.*

Water Tank a Notable Landmark. J. S. RAFFERTY. Am. City, 52: 63 (1937). A concrete elevated tank of 500,000 gallons capacity has been completed for the water-supply system of Cincinnati, Ohio. The concrete tank is supported by a circular concrete wall, surrounded by a brick and stucco wall and surmounted with a steep, conical roof. The general effect is somewhat that of a medieval tower.

The tank was designed under the Hewett System patent for pre-stressed tank walls. This required a series of 1-inch round hoops, with turnbuckles, placed on the outside of the concrete tank, after the forms had been removed. By pre-stressing the concrete wall with these hoops, the concrete is in slight compression, instead of tension, even after the tank is filled with water.—*Arthur P. Miller.*

Trends in Steel Tanks. R. H. BECK. W. Wks. Eng., 89: 830 (1936). First elevated tank with a suspended bottom was designed and built in 1894 at Laredo, Tex. Hemispherical type soon became the accepted standard because it was more economical and the stresses induced in this type of bottom are lower than in any other form. This type has been built in capacities as low as 5,000 gallons and as high as 1,200,000 gallons. The hemi-ellipsoidal bottom is replacing the hemispherical top. This was a natural development because with the hemispherical type the depth of bottom increases with the diameter. Tanks as large as 2,000,000 gallons have been built with hemi-ellipsoidal bottoms. Larger tanks are built with the toroidal bottom tank, and the radial cone bottom tank, both of which have a combination suspended and radial beam supported bottom. Trend now towards beautification of tanks.—*Lewis V. Carpenter.*

DISTRIBUTION

Ventilating Manholes by Hand Blower. E. T. CRANCH. W. Wks. and Sew., 83: 341 (1936). Satisfactory outfit made of hand-forge blower and air tube, costing $30.—*H. E. Hudson Jr.*

Experiences in Rehabilitating Large Water Mains. WM. G. BANKS AND A. CLINTON INGLEE. W. Wks. and Sew., 83: 327 (1936). This comprehensive paper tells of extensive work done at Newark, N. J., from 1933 to 1936. Riveted steel aqueducts had suffered loss of carrying capacity, Hazen's "C" having fallen to about 70 due to tuberculation. In general, pipe was not seriously weakened by internal corrosion, although water carried is active. 8000 feet of 42-inch conduit has been treated with a bituminous lining after hand scraping and machine brushing. Ventilating facilities and work procedures are thoroughly described. 27,800 feet of 48-inch pipe have been cleaned with main-cleaning machinery and given cement-mortar lining by machine. Description of this work and some experiences encountered is given with details on procedure and equipment. Careful testing controlled choice of cement and aggregate, and water-cement ratio used. Test on a 16,000-foot section of cement-lined conduit showed increase of Hazen's "C" to 124, a value probably higher than that for original pipe when new.—*H. E. Hudson Jr.*

Steel Water Tank on a Tall Tower Moved 350 Feet to a New Location. MILTON C. SHEDD. Eng. News-Rec., 117: 236 (1936). Brief description of moving of 75,000-gallon water tank on steel tower. Total height of structure is 125 feet. Provision (counterweights) was made for resistance to 50-mile per hour wind during moving. Original weight of tank was 65 tons and total weight when ready for moving was about 160 tons. Motive power was provided by truck with winch attachment. Actual time in traveling the 350 feet was about 20 hours. Raising tank and placing runways took about 15 hours and lowering structure on new foundation 12 hours.—*R. E. Thompson.*

Static Head Main Takes Place of Distribution Reservoir. W. A. KUNIGK. W. W. Eng., 90: 1 (1937). The original water system for Tacoma was built

of wood stove pipe. About 16 miles of this pipe is being replaced so as to permit carrying a higher static pressure for more efficient operation. The interconnections between the old low pressure and present high pressure system is made with automatic hydraulically controlled cone valves. Cone valves have been used wherever valves may have to be operated frequently, under full or unbalanced head conditions. The designer paid particular attention to the design of valves. A 12 x 16-inch manually-controlled hydraulically balanced needle type valve is used under a head of 325 feet and it functioned smoothly and with little vibration.—*Lewis V. Carpenter.*

The Use of Couplings. ROSSITER S. SCOTT. J. New Eng. W. W. Assoc. 50: 4, 399–413, 1936. Paper deals with Sleeve-type Flexible Pipe-Coupling and its development since 1880, the year of original design by S. R. Dresser. Coupling consists of a middle ring, 2 rubber gasket rings, and 2 follower rings connected by a set of bolts. Because this type of coupling allows each section of pipe to be practically hinged on its individual flexible gasket, each pipe can move independently and give considerable flexibility. Due to this freedom of movement, curves in a pipe line can be made as much as 4° or more in each joint. Rubber gaskets can be relied upon to last, first ones installed nearly 50 yrs. ago are still in successful service. Couplings, by varying strength of middle ring can definitely vary to meet any working pressure. Couplings have been found to be permanently water tight. Time of installation will be approx. 2 man-minutes per bolt, or 16 man-minutes for a 12 in. coupling and 56 man-minutes for a 48 in. coupling. Illustrations are given of adaptability to numerous conditions as well as a number of actual installation photographs.—*Martin E. Flentje.*

New Pipe Line in Swamp Meadows. ANON. Am. City, 52: 65 (1937). A 48-inch cast iron pipe line for supplying water to Bayonne, N. J., was laid across the swamp-like Hackensack Meadows. The pipe sections rest on concrete bents, which were poured on a twin row of piles.—*Arthur P. Miller.*

Large Butterfly Valves Used at Milwaukee Filtration Plant. ANON. W. W. Eng. 90: 216 (1937). The 200 m.g.d. water treatment plant for Milwaukee is using butterfly or balanced valves to control the flow in large mains. On the suction end of the low lift pumps, they have installed five 54-inch and two 54-inch butterfly valves. The delivery of the water to the distribution system is through a loop layout in which there are to be placed four 60-inch butterfly valves.—*Lewis V. Carpenter.*

Linings for Cast-Iron Pipe. THOMAS F. WOLFE. J. New Eng. W. W. Assoc. 50: 414 (1936). Linings for C. I. pipe are necessary because of many tuberculating water supplies. Reduced carrying capacity of pipes may be due to chemical characteristics of water, deposition of silt, choking by debris, partly closed valves, air in summits, numerous fittings and inferior pipe. If caused by chemical characteristics condition may be remedied by treatment of water, lining of pipe or combination of lining and treatment. Map is given showing areas in U. S. where tuberculation may be expected to be severe,

moderate and slight. Cement lining of pipes has been greatly improved and Hazen and William's coefficient of 150 may now be expected on new cement lined pipe and for an indefinite period after laying. Evidence is given to show that no change takes place in lining, coefficient (C) on pipe lined in 1922 did not change from a value of 135 in 11 yrs.; with present pipe a value of 140 may be used for design purposes. A tabulation of expected savings is shown for lined and unlined pipe under several conditions.—*Martin E. Flentje.*

Salvaging a 40-year old 48-inch Steel Force Main. STEPHEN H. TAYLOR AND GORDON C. LINBERG. W. Wks. Eng. 89: 1222 (1936). The New Bedford Water Board had a 40-year old 48-inch steel pipe line thoroughly cleaned and lined with steel mesh reinforcement on which 1¼ inch gunite cement mortar was placed. The pittings were so deep that they would have soon caused leaks. Improvement gave a main as good as new at fraction of the cost of renewing it.—*Lewis V. Carpenter.*

Simplified Analysis of Flow in Water Distribution Systems. J. J. DOLAND. Eng. News-Rec., 117: 475 (1936). Method for solution of problems concerned with distribution of flow in network, heretofore solved only by expensive electrical analogy methods, has been developed by Hardy Cross and was recently announced in Bulletin 286 of University of Illinois Experiment Station. Application of this analysis to water works grid system as described in this article is modification of problem ingeniously solved by Camp and Hazen using electric analogy (J. N. E. W. W. A. December, 1934). Briefly, method consists of assembling basic data in convenient form on diagram of system, assuming any flow distribution, calculating flow corrections due to errors in assumptions, applying corrections and repeating procedure until head loss between any 2 points by any possible path of travel is balanced. Method may be used for design purposes and is particularly adapted to investigation of existing systems under different operating conditions.—*R. E. Thompson.*

Analyzing Distribution Networks. THOMAS R. CAMP. Eng. News-Rec., 117: 693 (1936). Brief discussion of Cross-Doland (cf. previous abstract) and Camp-Hazen methods, with particular reference to time required. Electric network analyzer is employed in latter method.—*R. E. Thompson.*

Cisterns Store Water for Fires Where Earthquakes Menace Mains. Eng. News-Rec., 117: 223 (1936). Work is nearing completion in San Francisco on cross-town line of cisterns intended to increase protection against general conflagration that might occur in event of interruption of water supply by breaking of mains by earthquake such as in 1906. Nineteen additional concrete cisterns are being provided which, with those previously constructed, will provide chain of underground tanks not more than 1,000 feet apart extending entirely across city in north and south line. Before adequate distribution system had been constructed, underground storage was important part of fire protection system, 6 such cisterns being shown in 1852 map of city. Before end of century, 56 more, of brick construction and with capacities of 14,700 to 106,000 gallons, had been added. Unfortunately, just prior to 1906, when distribution system had been developed to such extent that fire protection

seemed assured, cisterns had fallen into disuse. In 1908, bond issue was voted to construct auxilary independent fire protection system of high pressure mains and pumps delivering water from San Francisco Bay. Old cisterns were repaired and 86 new ones built. Standard capacity is 75,000 gallons, dimensions being 30 feet diameter by 18 feet deep, 2 pumping engines being able to draw from each cistern simultaneously. No fixed pipe or other connections are provided, thus avoiding risk of disruptive stresses in event of earth movement. Cisterns are usually placed at street intersections and location is clearly marked by ring of basalt blocks set in pavement. When present program has been completed, total capacity will be 8,125,000 gallons, or 10,025,000 if old brick cisterns are included. In addition, and exclusive of domestic water system storage, there are storages of fresh and salt water in parks, swimming pools, etc., totaling 52 million gallons.—*R. E. Thompson.*

FILTRATION

Design Features of Denver's Newest Filtration Plant. L. R. Howson. Eng. News-Rec., 117: 78 (1936). Detailed description of 56-m.g.d. filter plant forming part of $8,000,000 Moffatt Tunnel project which will make Fraser River water from west slope of Rocky Mountains available for use in Denver. Natural flow of river results from melting snow at high altitudes and is available only 4 months in normal year, which coincide with 4 months of heavy consumption when water use is about double that of remainder of year. During this period plant will be operated at maximum capacity so as to utilize as much of flow as practicable for public water supply rather than for exchange for irrigation. During remainder of year, plant will be supplied from Ralston Creek reservoir. Fraser River supply will have average hardness of 2 grains per gallon compared with value greater than 7 of Platte River water, other source of supply. Saving in soap alone will be approximately $225,000 per year, which, for 25,000 acre-feet available, is equivalent to $9 per acre-foot, *i.e.*, 4.5 time revenue securable from sale for irrigation purposes. (Note: It was originally planned to use Fraser River water to restore flow of Platte River to volume required to satisfy prior rights. Cf. This J. 27, 1796, 1935.) At present time, Denver has 4 filter plants, 64-m.g.d. mechanical plant, 30-m.g.d. slow sand plant, and 2 old tub filter plants. Latter 2 will soon be retired from service. New plant, with other 2, will take care of requirements until at least 1950 and provision has been made for doubling capacity without superseding any of present investment. Site was selected 3 miles west of city at such elevation that clear water reservoir can be operated substantially as elevated storage for high-service area, enabling abandonment of Ashland Ave. high-service pumping station, thus effecting annual saving of $35,000. Head on pipeline delivering water to plant, which discharges into tangential-flow rapid mixing chamber, will vary from zero at 100 second-foot flow to 180 feet at zero flow. Surge control is provided for by automatic cone plug valve actuated by level of water in sedimentation basins. As precaution, inlet side of valve is protected by two 8-inch automatic pressure relief valves which, through open discharge into mixing basin, will relieve excess pipeline pressure to keep head within static range. From quick mixing basin, water passes to combined flocculating and sedimentation basin, 15 feet deep, providing 40

minutes' detention in flocculating compartment followed by 3 hours' quiescent settling. Flocculators are of paddle-wheel type, peripheral speed being about 1.25 feet per second. Velocity through sedimentation basin will be 1¼ feet per minute. About midway in basin, wood baffles are provided over which all water flows. Inlet and outlet are controlled by submerged weirs. Filter plant consists of 10 units, each having rated capacity of 5.6 m.g.d. when operating at rate of 2.8 gallons per square foot per minute (175 m.g.a.d.). Filters are of central gullet type, each bed consisting of 2 separate units, each of 2.8 m.g.d. capacity, operated from single set of control valves. Laterals are of cement-lined cast iron pipe, 4 inches in diameter, spaced at 9-inch centers. Gravel bed consists of 5 layers with total depth of 24 inches, varying in size from 2.5–1.5-inch at bottom to ¼–⅛-inch at top. Gravel is overlain with 5 inches of torpedo sand and 22 inches filter sand with effective size of 0.45–0.50 mm. and uniformity coefficient of 1.25–1.50. Each operating table will be equipped with floc detector. Chemical feed machines are provided for application of alum, lime, sodium aluminate, activated carbon, ammonia, and chlorine, with maximum flexibility in regard to points of application. Clear well will have capacity of 10 m.g. Wash water tank (225,000 gallons capacity), located at 40 feet higher elevation than plant proper, is underground. As wash water must be disposed of in local irrigation ditch, concrete detention reservoir is necessary to provide for storage and gradual release. During winter, wash water will be returned to mixing basin. Wash rate will be equivalent to 36 inches vertical rise per minute.—*R. E. Thompson.*

The Essex Border Utilities Commission's Filtration Plant at Windsor, Ontario. G. HUDSON STRICKLAND. 13th Ann. Rept. Ohio Conf. Water Purification, 80–4 (1937). The plant consists of an intake in the Detroit River, baffled mixing and coagulation basins and 10 rapid sand filters contg. 15 in. of graded gravel (6 in. bonded with weak cement grout) and 36 in. of 0.46-mm. sand. The original sand depth was 30 in. but was increased so that the sand would expand to the underside of the wash troughs during washing to enable the floc and silt to be carried off by the more rapidly moving water in the constricted areas between the troughs. This has been found most effective, reducing the amt. of wash water used and increasing the "hours of service" of the filters. Prechlorination, adopted in 1930, has improved floc formation, reduced the amt. of alum required, removed slimy growths on the walls of the basins and conduits and increased the length of filter runs. Since 1931, pre-ammoniation has been employed as an effective remedy for medicinal tastes: the dosages of Cl and $(NH_4)_2SO_4$ are 1.5 and 2.8 lb. per million gals., resp. The cost of pre-ammoniation is approx. 8¢ per million gals. Intermittent application of alum has been found satisfactory with raw water turbidities of under 30 p.p.m., i.e., 30 min. in each hr. for turbidities of 10 or less and 40 min. in each hr. for turbidities between 10 and 30 p.p.m. Blocking of the intake with frazil ice on several occasions has been remedied by reversing the flow. It has been observed that frazil ice does not form when the water contains 50–60 p.p.m. of turbidity or when the river is covered with ice.—*R. E. Thompson.*

Manifold vs. False-Bottom Collecting System. PHILIP J. O'CONNOR. 12th Ann. Rept. Ohio Conf. Water Purification. 32 (1937). The Warren filter

plant consists of 2 different types of units: the filters constructed in 1917 are of the false bottom design with umbrella-type strainers while those installed in 1921 are equipped with a cast iron manifold strainer system. In 1931, it was observed that a considerable amt. of sand had escaped through the underdrains of the latter filters. All of the filters were subsequently overhauled and it was found that the false bottom type were more easily reconstructed. It is concluded that the latter filters are more satisfactory.—*R. E. Thompson.*

New German Filtering Material. (Original article bears no title.) ANON. Ind. Eng. Chem., News Ed., 14: 433 (1936). Magnodoppelsatz, new German filtering material, is an entirely domestic product prepared from Westphalian dolomite rock. Principal use is in deacidifying drinking water by simple filtration.—*Selma Gottlieb.*

Raw Water Preparation Vs. Filter Design. MARSDEN C. SMITH. W. Wks. and Sew., 83: 350 (1936). Based on tests on plant and glass tube filters at Richmond, Va., it is concluded that a "filterability factor" of applied water determines filtration results, and that no known chemical or physical analysis can evaluate it. Slower filtration rates produce better water. With a good filterability factor, 0.65 mm. sand is satisfactory, but when this factor is bad, 0.45 mm. sand is needed. Filterability factor is profoundly affected by raw water preparation. Rate of increase of head loss increases as run progresses. High wash rate seems better than prolonged low rate or combination of low and high rates. Two-inch glass tube filters have given erratic results in comparison to plant filters. For good operation at peak loads, it is necessary to either use better preparation of raw water or to put reserve filters into service. —*H. E. Hudson Jr.*

Hydraulic Valve Operation Controlled by Small Motor-Driven Pumps. HAROLD VAGTBORG. Eng. News-Rec. 117: 335 (1936). Brief description of hydraulically operated valves of new 15-m.g.d. water softening plant at Shenandoah, Iowa, which are controlled by small reversible motors driving oil pumps located on valves. Usual pressure pipe lines controlled by 4-way cocks are eliminated, operating table and valves being connected only by conduit carrying 110-volt wiring for motor and 6-volt wiring for positive indicating system. Water supply is derived from 4 remote-control wells located 1,800–5,000 feet from plant. Starting and stopping switches with indicating lights are located on main switch board at plant. Lubrication of well pumping equipment is effected by solenoid operated oil feeders which operate only when pump motor circuit is closed.—*R. E. Thompson.*

Anthrafilt Increases Capacity of Pressure Filters. ARTHUR T. COOK. W. Wks. Eng. 89: 1215 (1936). Passaic, N. J. Valley Water Commission built a pressure filter plant which was equipped with anthrafilt. Part of the original installation used sand for filters and after some experiments all sand was removed and anthrafilt used throughout. The filters are washed twice a day and the rate is one-half the wash water rate required for the sand beds. The time required to use a filter is approximately double that required for the sand at the higher rate. As a rule, the anthrafilt shows better results in the removal

of manganese, iron, and amorphous matter. Experiments indicate that a depth of 16 to 18 inches will give as good results as thicker beds. Estimated that the use of anthrafilt saved an investment of $160,000 which would have been required to increase the pressure filter plant to the required capacity using sand beds.—*Lewis V. Carpenter.*

SOFTENING

Colloid Remedies Against Water Hardness Damage in Textile-chemical Procedures. AUGUST CHWALA. Oest. Chem.-Zeit. 40: 101 (1937). Review of methods of inactivation of calcium and magnesium salts by water softening, colloidal dispersion of lime soap by excess sodium soap, sulpho-compounds, fatty acid-condensation products, natural colloids etc. and by inactivation by hexametaphosphates is given and economy discussed. Due to lower cost of water softening wetting and detergent agents may not be used to replace water softening.—*Manz.*

Softening of Drinking Water. H. HAUPT AND W. STEFFENS. Das Gas— Und Wasserfach. 80: 72 (1937). A review of the reasons for central water softening plants with description of water softening methods in U. S. Brief description is given of methods used at Evansville, Daytona Beach, Thomasville, Bloomington, St. Louis. Authors point out former figures for savings in soap and heat losses due to boiler scale caused by use of hard waters were considerably higher than later more accurate studies have shown them to be. Conditions in Germany where ground water or other supplies are used seldom necessitate softening of municipal supplies.—*Martin E. Flentje.*

Rebuilt Filtration Plant Softens River or Well Water. ANON. Am. City. 52: 49 (1937). The water-supply of Oskaloosa, Iowa is derived from hard, turbid river water and hard well water. The treatment plant is designed for using either or both of the above sources. The water is aerated and floculated after being mixed with iron salts, lime and or soda. After settling it is recarbonized with carbon dioxide generated in a boiler from which hot water is obtained for the lime feed. After filtration and chlorination, the water is pumped into an elevated storage tank.—*Arthur P. Miller.*

Report of the Water Pollution Research Board (Eng.) for 1935. 51 pp. H. M. Stationery Office, Adastral House, London, price one shilling. Materials for softening water by base exchange can be prepared from British clays, some being equal in base exchange value to imported minerals and more resistant to disintegration. Most satisfactory results were obtained by treating clays with hydrochloric or sulphuric acid, drying, grading, baking at 600°C and finally treating with solutions of sodium silicate and aluminate. Some of synthetic resins prepared from certain phenols and tannins are capable of removing as much calcium and magnesium from water as an equal weight of commercial base-exchange minerals. Other resins prepared from aromatic bases e.g. aniline, remove acidic radicals. Water treated with tannin, resin and then with aniline resin had total solids reduced from 33 to 1 parts per

100,000. Two or three applications removed most of salt from sea water. Water containing 1 to 10 parts per 100,000 of lead, zinc and tin had all detectable amounts of metals removed by passing through sodium, potassium, ammonium and magnesium zeolites, copper removed by manganese zeolite. Materials regenerated with 10 percent salt solution, but sodium nitrate necessary when lead adsorbed to prevent precipitation of chloride. Household zeolite filters are useful for removal of all lead from drinking water, by measuring water and determining lead in zeolite average concentration of lead in water supply is ascertained.—*W. G. Carey.*

Zeolites and the Zeolite Process of Water Softening. CHARLES P. HOOVER. 13th Ann. Rept. Ohio Conf. Water Purification: 39 (1937). An exceptionally complete discussion of water softening by base exchange, including the history of the process, litigation over patent rights, properties of natural and synthetic zeolites, methods of testing zeolites and the factors to be considered in the design of zeolite softening plants, e.g., the presence of Fe in the raw water, methods of regulating the final hardness and rendering the treated water non-corrosive, etc. A bibliography of 30 references is appended.—*R. E. Thompson.*

Iron and Manganese Removal from Waters Containing Humus in Closed Rapid Filters. A. MARSCHNER. Gas und Wasserach. **79**: 818 (1936). Three water supplies with high humus content have been freed from iron and manganese in closed aeration and filtration system. Water with compressed air is forced into scrubber filled 3.5 m.m. coke, followed by filtration through graded gravel beds. Each water had its own requirement as to velocity and amount of air, and those with least iron and manganese, but higher humus, were most difficult to treat.—*W. G. Carey.*

Effect of Low pH Waters on Zeolites. A. S. BEHRMAN AND H. GUSTAFSON. Ind. Eng. Chem., **28**: 11, 1279 (1936). Reduced base-exchange capacity of zeolites at relatively low pH (in absence of true mineral acidity) is not due to disintegration of zeolite but to new equilibrium conditions at low pH. New equilibrium at lower level of base exchange capacity is established quickly, and active life of zeolite is not shortened. First water softened after regeneration has pH considerably higher than that of raw water, decreasing steadily until at end of run, it is lower than that of raw. This effect is so uniform that it may be used, under proper conditions, as basis of automatic regulation of complete softening, regeneration and backwash cycle.—*Selma Gottlieb.*

Operating Results of the Findlay Water Softening Plant. A. V. FOLTZ. 12th Ann. Rept. Ohio Conf. Water Purification: 25 (1937). Operating experiences and results are reviewed. The water supply, derived from wells and springs, is softened by the excess lime and recarbonation process, sufficient softened water being further treated by the base exchange method to reduce the final hardness to the desired figure. During the period March–Aug., 1932, 48% of the lime-softened and filtered water was passed through the zeolite units. The total hardness averaged 376 p.p.m. in the raw and 88 p.p.m. in

the treated water. The av. cost of chemicals for removing 1 p.p.m. of hardness per million gals. was as follows: lime softening (including alum for coagulation and coke for recarbonation) 5.1¢, zeolite softening 11.9¢, both 7¢. The av. cost of removing 1000 grains of hardness was 0.119¢. The salt required for regenerating the zeolite averaged 0.51 lb. per 1000 grains of hardness removed: wash and rinse water totaled 7.7% of water treated. Difficulty has been experienced with corrosion and clogging of the orifices of the CO_2 grid piping, even monel metal being attacked. The filter (rapid sand) runs averaged 49 hrs. and the wash water 2.35% of the water treated. The excess lime treatment produces a water that does not require chlorination. The quick lime used is unloaded by the vacuum system at a total cost of 21¢ per ton. (See following abstract.)—*R. E. Thompson.*

Discussion of Operation Results of the Findlay Water Softening Plant. C. P. HOOVER. 12th Ann. Rept. Ohio Conf. Water Purification: 30 (1937). The results obtained (cf. previous abstract) have confirmed the est. made when the plant was designed, i.e., that the chem. cost of removing carbonate hardness with lime would be ½ that of the base exchange method and that the chem. cost for removing non-carbonate hardness would be 20% less by the zeolite process that with soda ash. The selection of a softening process for a particular location depends upon the following factors: (1) Ease of disposal of sludge. (2) The chem., phys. and bacterial quality of the water. (3) The cost of the chemicals required. (4) The abundance or otherwise of the supply. The lime or lime-soda processes are particularly adapted to the treatment of waters contg. a relatively large proportion of carbonate hardness, especially if they are subject to contamination, are turbid or contain large amts. of Fe and Mn. The zeolite process is to be preferred for clear waters which contain a relatively large proportion of non-carbonate hardness, provided the wash and rinse water required, which ranges from 5 to 25%, would not be a serious objection. Water deficient in SO_2 will dissolve it from synthetic zeolites. An advantage of the lime process is the reduction of the content of total solids. It is pointed out that in water contg. Na_2CO_3 or $NaHCO_3$, as is the case in the Findlay treated water, the alky. is not a measure of the carbonate hardness and the non-carbonate hardness cannot be detd. by the soda reagent method, although the sum of these 2 detns. accurately represents the total hardness, the Na_2CO_3 or $NaHCO_3$ increasing the alky. and reducing the soda reagent value a similar amt. (all expressed as $CaCO_3$).—*R. E. Thompson.*

STREAM POLLUTION

The Problem of Public Waters Pollution Control in New Hampshire. C. D. HOWARD. Health (N. H. State Board of Health), June, 1936. The author presents a discussion of the powers, duties and limitations of the N. H. State Board of Health relative to the control of pollution of public waters under existing laws. The Board is broadly authorized to require provision of any improvement in a public water supply that it may deem essential for the public good, and to order such improvement to be made, under penalty of not less than $100 for each day of failure to comply.—*G. C. Houser.*

Industrial Waste Pollution Surveyed. Eng. News-Rec., 117: 636 (1936). Details given from report on industrial wastes in New Jersey presented before American Chemical Society by Dr. Willem Rudolfs. Survey covered 1,792 plants in various parts of state, definite information and samples being obtained from 1,213 industries. Analyses were made on 410 representative types of wastes. Samples of wastes from 205 different industries were selected for special study to determine volume and strength of waste produced per employee per day. Tabulation of results obtained is given. Water consumption by industries from which samples were selected amounted to 54.6 m.g.d., while liquid wastes discharged amounted to 43.651 m.g.d. Table is included showing estimated waste produced per day by all industrial groups for entire state in terms of tons of solids (total, suspended, soluble, etc.), oxygen consumed, chlorides, and wet sludge. Figures for total solids and oxygen consumed are 1,192 and 106, respectively. Compared with the 900,000 tons of sewage solids discharged yearly into New Jersey streams, suspended material produced by industries, converted to same density of sewage solids, appears to be well over 700,000 tons. On basis of oxygen demand, population equivalent of industrial wastes is 3,100,000., *i.e.*, two-thirds of domestic sewage from entire population.—*R. E. Thompson.*

Clean Streams for Wisconsin. Eng. News-Rec., 117: 310 (1936). Data given from report by L. F. Warrick on progress on stream pollution program started 10 years ago. Material clean-ups have been effected in 28 major drainage areas into which state was divided. Of total of 244 public sewer systems, 136 now have treatment facilities and 12 new plants are under construction. Brief details included regarding progress in various areas and developments in treatment of different industrial wastes.—*R. E. Thompson.*

Colorado to Check Pollution of Streams Within the State. Eng. News-Rec., 118: 32 (1937). Municipalities and industries in Colorado have been notified by B. V. Howe, State Sanitary Engineer, that hitherto unenforced 1931 law prohibiting pollution of streams will be rigidly enforced. Notice that they must build sewage disposal plants has been served on cities not already so equipped. Likewise, beet sugar companies have been informed that they will be required to treat wastes as soon as communities conform to requirements for sewage treatment. Mining mills and smelters will also be forced to discontinue discharging waste into streams. Conditions are especially bad in Arkansas River, which is used extensively for irrigation. State laws provide that no domestic sewage nor water containing domestic sewage in amount and condition such that bacteria of coli-aerogenes group are present in quantities of 10 or more per c.c. small be used to irrigate or be permitted to overflow any fruits or vegetables for human consumption, edible portions of which grow in ground or above it within 1 foot of surface, except with written permission of State Board of Health.—*R. E. Thompson.*

Chicago Sanitary District Makes Semi-Annual Report. Eng. News-Rec., 118: 110 (1937). In report to Supreme Court, District indicates that 41 per cent

of total sewage is now being treated and that net diversion from Lake Michigan, limited by Court to 5,000 second-feet, averaged 4,861 second-feet up to December 31, 1936. To date $135,284,000 has been expended on sewage treatment works and $64,158,000 is still to be spent.—*R. E. Thompson.*

Stream Pollution in New Jersey. WILLEM RUDOLFS. Ind. Eng. Chem., 28: 1294 (1936). From survey of nine counties of most industrialized area of New Jersey, it is estimated that industries of state annually discharge into streams wastes equivalent to 700,000 tons of sewage solids, compared with 900,000 tons from domestic sewage. Settleable wet sludge is nearly 100,000 tons per year, compared with about 450,000 tons of wet domestic sewage solids. "Population equivalent" of wastes from all industries is about 3,100,000, or two-thirds of state's discharge of domestic sewage. Wastes of different industrial groups vary considerably in oxygen requirements and capability of sludge production.—*Selma Gottlieb.*

Treatment of Fiberboard Waste. FOSTER DEE SNELL. Ind. Eng. Chem., 29: 238 (1937). Sedimentation for 24 hours reduced suspended matter of fiberboard waste from 134 to 15 p.p.m., without chemical treatment. Filtration was not satisfactory. Waste contained pigment and paper stock as chief solid constituents.—*Selma Gottlieb.*

Chemistry of Main River Water during Alternating Seasons. W. NOLL. Archiv. für Hydrobiologie 31: 58 (1937). Chemical data of Main river water examination for a distance of 105 miles are recorded and influence of tributaries on river water composition discussed. In sections of completed canalization decrease of oxygen content due to decrease of velocity of flow and elimination of ponds with luxurious plankton growth is remarkable.—*Manz.*

PUBLIC HEALTH

Restrictions upon Bathing in Public Waters. Health (N. H. State Board of Health), July, 1936. The New Hampshire law forbids bathing in any waters constituting a public supply within such limits as the State or local board of health may fix. The State board is also empowered to make any kind of a sanitary regulation for public water supplies that it may see fit. In practice, the special regulations as to quite a number of individual sources forbid bathing therein.—*G. C. Houser.*

Carrier-Borne Typhoid Fever in New York State. E. L. STEBBINS AND E. REED. Am. Jour. Pub. Health, 27: 233 (1937). The epidemiological investigation of sporadic cases of typhoid fever has resulted in the discovery of 72 percent of all known chronic typhoid carriers. At the time of the discovery of each carrier a careful history of the individual's experience with typhoid fever is obtained. All cases of typhoid fever occurring within the household of a known carrier subsequent to the year of his illness have been considered as due to the carrier. The risk of household exposure to carriers has been studied with respect to various time scales. An attempt has been made to

determine the degree of this risk by a study of the incidence of typhoid fever in the households of carriers. Typhoid vaccination has been shown to be effective in the protection of certain groups of individuals likely to be exposed and has been recommended for all household contacts of typhoid carriers.—*H. E. Babbitt.*

Resolution Adopted by the Joint Committee on Health Problems in Education of the National Education Association and the American Medical Association. The Commonhealth (Mass. Dept. of Public Health), 23: 164 (1936). In June, 1936, the Joint Committee adopted a resolution, earnestly recommending to all school boards and school executives that surveys be instituted by competent engineers to ascertain whether or not the danger of back siphonage and consequent pollution of water supply mains exists in plumbing installations within their jurisdictions, and that such surveys be followed by prompt corrective measures.—*G. C. Houser.*

WATER QUALITY

Lead Poisoning from Drinking Water. A. L. Burgdorf. Conn. Health Bull., 50: 308 (1936). Author describes case of lead poisoning, occurring in farm family, which was traced to the drinking water. The supply was obtained from a well and conducted through ¾-in. lead pipe to the farmhouse. During the summer-time a long column of water was kept stationary in this lead pipe for periods of 12 hours or more. During 18 years the family living in the house did not drink very much water from this system in the summer, because it was warm. Then an icebox was installed, after which time water from this system was used after cooling. Development of symptoms of lead poisoning followed.—*G. C. Houser.*

A Water-borne Outbreak of Paratyphoid A Fever. Joseph P. Franklin and C. H. Halliday. Can. Pub. Health J. 28: 82 (1937). An outbreak of 37 cases of paratyphoid A among a resident population of 133 persons, with 4 cases among visitors, in Vindex, Md., was traced to a resident who had been visiting elsewhere. Pollution of the common well serving the community by seepage from the privy of the home of the first case was demonstrated by uranin and salt tests. B. paratyphosus A was isolated and identified as the causative agent. The epidemic was preceded by an outbreak of 27 cases of dysentery. —*R. E. Thompson.*

Public Health Aspects of the Treatment of Water and Beverages with Silver. James Gibbard. Am. Jour. Pub. Health. 27: 112 (1937). Silver is one of the most active ions. It possesses bactericidal action and even relatively high doses do not produce any immediate pathological or physiological change. There is hardly a food industry in which water plays a part that silver treatment has not been recommended as a valuable agent. As a result of many experiments the conclusion has been reached that silver possesses bactericidal action and it is recommended that the use of silver as a preserving agent in foods, or as a method of treating polluted water be carefully considered by public health officials.—*H. E. Babbitt.*

Variations in the Lactose-fermenting Flora of an Impounded Water Supply. CLARENCE BAHLMAN. 14th Ann. Rept. Ohio Conf. Water Purification 126 (1937). Further data are given regarding the sudden appearance of lactose-fermenting organisms in the Blanchester water supply (cf. previous abstract). NH_3-Cl treatment, with a residual Cl content of 0.25–0.5 p.p.m., was ineffective. The majority of the confirmed tests have been found due to aerobic spore-bearing lactose-fermenters which give pin-point colonies with a green metallic sheen on eosin methylene blue agar. The secondary lactose broth tubes are now being subjected to a temp. of 80–85° for 20 min. prior to incubation.—*R. E. Thompson.*

BACTERIOLOGICAL RESEARCH

Is Escherichia Coli a Derivative of Aerobacter Aerogenes in the Human Body? (An abstract) M. P. HORWOOD AND R. A. WEBSTER. Jour. Bact. 33: 21 (1937). Seven samples of the ileostomy discharge and four specimens of the rectal discharge from a male patient taken during a period of about eleven months were examined for colon-aerogenes organisms. During the tests, 101 colonies were isolated from the rectal discharges and 120 colonies from the ileostomy discharges. All the organisms from both sources gave acid and gas in glucose broth, lactose broth and brilliant green lactose bile, 2 percent. Tests on differential media and microscopic appearance indicated that the 101 cultures from the rectal discharges were typical fecal strains of *Escherichia coli*. Among other differential tests of the 120 cultures isolated from the ileostomy discharges, the authors report that only 14.2 percent produced indol; 12.5 percent gave a typical reaction for *Escherichia coli* on eosin methylene blue agar while 87.5 percent gave the characteristic appearance of *Aerobacter aerogenes*; only 11.7 percent gave typical reactions for *Escherichia coli* in methyl red, Voges-Proskauer, uric acid and sodium citrate, while 89.3 percent gave reactions typical of *Aerobacter aerogenes*. "From the results it would appear that the normal bacterial flora in the small intestine consists essentially of *Aerobacter aerogenes* but that following passage of the intestinal contents into the large intestine a change occurs which transforms *Aerobacter aerogenes* into *Escherichia coli*. It is possible, therefore, if this transformation is not complete, that *Aerobacter aerogenes* may have much greater sanitary significance than is accorded to it at present."—*Ralph E. Noble.*

Succession of Colon-typhoid Organisms in Normal Human Feces. (An abstract) LELAND W. PARR. Jour. Bact., 33: 75 (1937). In a study of the normal flora more than 6,000 strains from direct plating of 210 fecal specimens from 32 healthy babies and 59 normal adults were investigated, over 1700 in pure culture detail, the balance only for utilization of citrate as a sole carbon source. Colon bacilli were encountered in 92.3 percent, aerogenes 25.2 percent, and coli-aerogenes intermediates in 20 percent of the specimens. Paracoli were found 21 times, cellobiose-fermenting coli 52 times, H_2S-positive coli once, gelatin-liquefying coli once, chromogenic coli twice, *bacillus coli-mutable* 8 times, *Eberthella typhosa* twice, gelatin liquefying aerogenes 14 times and *Pseudomonas* twice. *Shigella, Salmonella, Proteus* and *Alcaligenes*

were not found. Bacillus "P" of Clemesha (?) was isolated from 11. This is the typical group of bacteria found in long stored feces and is often confused with pathogenic group members. One subject was examined 92 times and of others multiple examinations were made. Serial study adds to the evidence from single studies that the fecal flora of the healthy is subject to such great variation that a number of points in sanitary, systematic and pathogenic bacteriology may have to be restated.—*Ralph E. Noble.*

Studies of Freshwater Bacteria. III. Quantitative Aspects of the Direct Microscopic Method. ARTHUR T. HENRICI. J. Bact., 32: 265 (1936). The use of a direct microscopic method for measuring bacterial activity in freshwater habitats is discussed; statistical and other errors and the limitations of accuracy, are pointed out. The relationship of the number of bacteria to the duration of exposure of the slides has been studied. It is found that the curves for this relationship vary with, and are probably characteristic of, different habitats. There has been found a limited positive correlation between plate counts and microscopic counts. Reasons for this correlation and its limitation are discussed. It is recommended that if the method is used quantitatively, each observation be made on 2 slides 50 x 75, to be suspended in the water back to back; that the duration of exposure be roughly adjusted to the habitat, and that two observations of differing duration be made for each habitat, trying for a count of 100 or more per field (roughly 13,000 per sq. mm.); and that 50 fields be counted from each slide, from an area in the central portion.—*Ralph E. Noble.*

The Rôle of Non-Fecal Bacteria in Water Supplied to Creameries. DONALD B. SHUTT. Can. Pub. Health J., 27: 226 (1936). Water free from intestinal bacteria and therefore safe for human consumption may contain bacteria which will give rise to "surface flavor" in butter following washing. Several types of bacteria, derived from surface drainage, especially from swampy land, will cause this condition. All proteolytic or lipolytic bacteria are looked upon with suspicion. The fluorescent group, of which *Ps. fluorescens* is the most important, are particular offenders. This group may be detected by plate culturing on standard agar (pH 7.2) and incubating 4 days at 25°. Greenish-yellow discoloration of medium surrounding the colonies identifies the type. In one case, notwithstanding that the bacteria had been eliminated from the (municipal) water supply, the trouble continued and was traced to swamp residue in the meter screen, water passing through the meter having bacterial count in excess of 10,000 per cc.—*R. E. Thompson.*

A Study of Non-colon Group Lactose Fermenters in Water Supplies. E. B. EVANS. 14th Ann. Rept. Ohio Conf. Water Purification, 110 (1937). Since construction of the dams on the Ohio River, the number of non-confirming presumptive positive coli-aerogenes group tests on the chlorinated Cincinnati water have increased: during period 1932–4, only 15 percent of the 1648 positive presumptive tests confirmed. Increased Cl dosages having failed to eliminate the organisms responsible, an effort was made to det. their nature. Transfers were made from 64 presumptive positive lactose broth tubes to brilliant green

bile, Dominick-Lauter broth, Ritter's fuchsin broth, Salle's crystal violet broth and eosin methylene blue agar and to lactose broth for the spore test. The results of these tests, which are tabulated, indicate that the spurious presumptive positives are due to aerobic spore-formers, anaerobes or possibly bacterial synergism. Attempts to isolate an anaerobe were unsuccessful but an aerobic spore-former which produces gas very slowly and a non-gas producing aerobic spore-former were isolated which together gave violent gas formation and produced butyric acid. The cultural characteristics of these organisms are described. If inhibitory media had been used for routine tests the conditions described would not have been observed.—*R. E. Thompson.*

Sudden Appearance of Resistant Lactose-Fermenting Bacteria in the Blanchester Water Supply. CLARENCE BAHLMAN. 13th Ann. Rept. Ohio Conf. Water Purification, 92 (1937). The water supply of the village is derived from a small impounding reservoir, the purification plant consisting of mixing and coagulation basins and 2 filters. Although the turbidity averages only 30 p.p.m., with a max. of 100, 3–4 grains of coagulant per gal. is required. In 1929, iron and lime coagulation was found more satisfactory and economical and was substituted for alum treatment, enabling discontinuance of chlorination, which gave rise to moldy and algal tastes. Several years later, a marked increase in gas-forming bacteria occurred in the filtered water and although chlorination has been resumed and there is 3–4 days' contact with 5–15 p.p.m. of caustic alky. these results have persisted, but to a lesser degree, true coli-aerogenes positives also being occasionally recorded. As the untreated water is of good quality, these results are difficult to explain. In discussion, H. E. Jordan suggested that packing materials or decayed wood around the plant might be responsible.—*R. E. Thompson.*

Chemical and Bacteriological Examination of Drinking Water. H. MOHLER. Schweiz. Verein von Gas- und Wasserfachmännern, Monatsbulletin, 16: 209 (1936). Methods prescribed in new (fourth) edition of Swiss alimentary codex for chemical and bacteriological examination of drinking water are discussed. Detailed instructions are given for collecting and continuous testing of samples from springs newly taken into service, taps, existing wells, and boreholes for new groundwater works. Having regard to peculiarly favourable conditions which prevail in Switzerland, following standards are laid down for pure water: —potassium permanganate consumption, 6 p.p.m. (i.e. oxygen consumed, 1.5 p.p.m.); free ammonia, 0.02 p.p.m.; albuminoid ammonia, 0.05 p.p.m.; nitrate, 20 p.p.m. NO_3 (i.e., nitrate nitrogen, 4.5 p.p.m.); chloride, 10 p.p.m.; and nitrite must be absent. Total count at 20–22°C. shall not exceed 100 for spring water, nor 10 for groundwater. For *B. coli* test, glucose-neutral-red-agar and lactose-broth are used; for evaluation, with BULIR mannose broth, spring water must be negative in 20 ml. and groundwater in 100 ml.—*Manz.*

INDUSTRIAL WATER USE

Modern Water Purification in the Brewery and Distillery. F. J. LAMMERS. Water Works and Sewerage, 83: 3, 95–99 (1936). Breweries need four kinds

of water: clear, palatable water for brewing; clear, sterile, iron-free water for washing and rinsing; boiler feed water meeting the usual requirements; and non-scale-forming, non-corrosive, non-clogging water for cooling. Distilleries require clear, palatable water for mashing; cooling water; boiler feed water; and water suitable for blending. Desired chemical compositions for these waters are described. Treatments generally favored to enable these requirements to be met are listed as: lime and zeolite softening with sand filtration, coagulation, sedimentation, sand and disk filtration, superchlorination and dechlorination with granular active carbon, chlorination, pH correction with acids, distillation, and filtration through activated carbon for taste and odor removal. Modern treatments are lauded.—*H. E. Hudson Jr.*

Water Supply a Large Factor in Economical Train Operation. F. P. TURNER. Railway Age 101: 586 (1936). The Norfolk and Western Ry. has provided many new and improved locomotive water facilities during the past 20 yrs. to take care of the changes in transportation and also the increase in size of locomotive tenders to 21,000 and 22,000 gals. Treatment was started in 1905 and now water is softened at all important stations using lime, soda ash and/or sodium aluminate. Cost of treatment varies from 2 to 5 cents per 1,000 gals. Elevated steel storage tanks of 100,000 gal. capacity have been erected with foundation and frame suitable for add. 100,000 gal. when required.—*R. C. Bardwell.*

CORROSION

Scale and Corrosion Control in Aqueous Systems. DAVID W. HAERING. W. Wks. and Sew., 83: 275 (1936). Various types of treatment for preventing scale and corrosion at elevated water temperatures are discussed with emphasis on increasing use of organic substances, particularly glucosides. Careful and complete analyses are essential to good control and effect of various ingredients is mentioned. Sodium silicate is proven no panacea. Causes of corrosion and tests of their effects are described. Chemical corrosion preventions are (a) removal of objectionable ingredient, and (b) passivation or formation of protective coating. Examples of the former—deoxygenation and distillation; of the latter—sodium silicate, chromates, and amines. The latter have limited applications. "One-shot" treatments are unsatisfactory, while continuous proportional application of agents is usually good.—*H. E. Hudson Jr.*

The Corrosive Action of Various Types of Water on Household Plumbing. C. P. HOOVER. W. Wks. and Sew., 83: 384 (1936). Six hot water heaters and galvanized iron tanks were operated at Columbus, Ohio, for a year, each receiving different water. Careful analyses were made and are given. While results are regarded as preliminary, the following tentative conclusions are drawn: (1) low alkalinity water with mostly normal carbonates is more corrosive than water without normal carbonates; (2) bicarbonate calcium and magnesium alkalinity produces best protective coating; (3) pH is more important than dissolved oxygen in rate of corrosion; (4) corrosion by normal carbonates water concentrates at pinholes in galvanizing; (5) products of such corrosion retard corrosion rate.—*H. E. Hudson, Jr.*

Chemical Action of Water and Its Effect on Water Mains and Joint Packing Materials. W. AUSTEN. Gas- u. Wasserfach, 79: 55 (1936). Various corrosion theories are reviewed and rôle of oxygen in forming coatings resistant to further corrosion, especially in presence of carbon dioxide and hardness, is stressed. Addition of oxygen may be necessary in some waters, to minimize corrosion. Oxygen also facilitates manganese removal. External corrosion of mains may be caused by dissolved substances in ground water: hydrogen sulfide causes corrosions of cast iron mains with formation of ferrous sulfate and traces of sulfuric acid, leading to further corrosion. Lead has been found satisfactory for joints, and aluminum has now been suggested. Pure aluminum is corrosion-resistant; but its alloys are not. Cement joints are not satisfactory.—*R. E. Thompson.*

Measurement of Stray Currents in Pipe Lines. BÖNINGER. Gas-u. Wasserfach, 79: 5 (1936). General problem of electrolytic corrosion of pipe lines involves identification of magnitude and potential of current and its origin. Simultaneous potential readings at several locations at frequent intervals may be required to determine source, which is generally a street railway. Special recording galvanometer (using photographic film) has been of service. Examples given. Current of 0.75 ma. per sq. dm. per year will destroy following metal thicknesses (in millimeters): aluminum 0.0855, copper 0.174, iron 0.0862, nickel 0.0802, lead 0.221, zinc 0.116.—*R. E. Thompson.*

Scale Formation and Corrosivity of Hot Water—Measures Against. FRIEDRICH FRHR. VON HÜLLESSEM. Gesundheits-Ingenieur 60: 13 (1937). Precipitation of calcium carbonate on hot water systems due to supersaturation or deacidification with lime water does not prevent corrosion of iron pipe even by waters of excessive carbonate hardness scale formation and pitting being always associated. Corrosion is stopped by absorption of oxygen by sulfite without catalyzation of the reaction with copper salts presence of metallic copper in hot water systems being responsible for rapid desoxydization with moderate overdosing. Excess carbon dioxide simultaneously may be eliminated by dosing sodium sulfite with sodium hydroxyde. It is noted that on oxygen free hot water no deposition of scale even from supersaturated water takes place.—*Manz.*

Organic Inhibitors of Corrosion. CHARLES A. MANN, BYRON E. LAUER, AND CLIFFORD T. HULTIN. Ind. Eng. Chem., 28: 1048 (1936). Relative effectiveness of various organic amines as corrosion inhibitors can usually be explained from structure. Changes in constitution causing ring constituents to incline away from perpendicular to metal surface increase covering power and therefore effectiveness as inhibitor. Configuration of inhibitor ion determines closeness of packing in covering layer and of penetrability of film to hydrogen ion. Lower film porosity means greater inhibiting value.—*Selma Gottlieb.*

CHEMICAL METHODS

Volumetric Determination of Bromide. I. M. KOLTHOFF and H. YUTZY. Ind. Eng. Chem., Anal. Ed. 9: 75 (1937). In presence of much chloride, small

amounts of bromide are oxidized to bromate with sodium hypochlorite in presence of sodium dihydrogen phosphate and sodium chloride. Excess chlorine is destroyed with sodium formate, bromate allowed to react with potassium iodide in acid solution in presence of ammonium molybdate as catalyst, and liberated iodine titrated with sodium thiosulfate solution, using starch indicator. Correction is made for blank similarly treated. For about 0.8 mg. of bromide, accuracy is within 1 percent, and for about 8 mg. or more, accuracy is within 0.3 percent.—*Selma Gottlieb.*

A Standard Quinhydrone Electrode. VERNER SCHOMAKER AND D. J. BROWN. Ind. Eng. Chem., Anal. Ed., **9**: 34 (1937). Quinhydrone half-cell using potassium tetraoxalate solution saturated at 0°C. can be readily made without use of balance or volumetric apparatus. Directions for making, and E.M.F. readings against calomel half-cell are given.—*Selma Gottlieb.*

New Method for Determination of Chlorine Fixation in Drinking Water and Sewage. H. IVEKOVIC. Zeitschrift für analytische Chemie, **106**: 176 (1936). In determination of chlorine fixation by FROBOESE method, low values are obtained because of reappearance of blue color, due to nitrites either originally present in the sample, or formed during action of chlorine. For water containing oxidizable nitrogenous matter of organic or inorganic nature, as, for instance, high ammonia content, and especially for sewage, this procedure is really unsuitable. To overcome this interference, back-titration of excess active chlorine in bicarbonate solution, without addition of potassium iodide, is needed. Following procedure is recommended. One hundred ml. of sample with 20 ml. of 0.02 *N* sodium hypochlorite solution are held for 30 minutes in boiling water bath, then cooled for 5 minutes with tap water and 10 ml. 0.05 *N* sodium arsenite solution added, and, after mixing, 1 drop methyl-orange. Ten per cent hydrochloric acid is then added from a burette until color becomes red, then sufficient sodium bicarbonate and 1 ml. starch solution are added and excess arsenite is back titrated with 0.02 *N* iodine solution. A blank of redistilled water is treated in exactly the same manner; difference between the two titrations multiplied by 7.09 represents chlorine fixation. Ratio of chlorine fixation to permanganate consumption exceeding unity is not always an index of recent fecal pollution.—*Manz.*

Testing of Nitrites and Nitrates in Drinking Waters. JOSÉ CASARES GIL. Chem. Zeit. **60**: 896 (1936). Color development with potassium iodide starch solution nitrite concentration being equal is hastened with increased iodide or acid concentration. In order to avoid decomposition of Griess-reagent and to simplify field tests solid mixture of 3 parts sulfanil-acid and 1 part alpha-naphthylamine is used; to 10–15 ml. of the sample a pealike amount of powdered reagent is added; with 0.01 p.p.m. N_2O_3 color develops after 2–3 minutes. Same test holds for nitrate detection after reduction with a trace of zinc dust, nitrites being eliminated by boiling with methanol and acetic acid.—*Manz.*

Conductivity of Calcium Bicarbonate and Determination of Sulphates and Total Hardness in Natural Waters by Electrical Conductance. WILHELM

NÜMANN. Die Naturwissenschaften 24: 693 (1936). Electrical conductance is measured in original samples and after neutralization with hydrochloric acid in order to convert calcium bicarbonate to calcium chloride; the second value represents conductivity of the just formed calcium chloride which may be calculated from standard conductivity curve plus unchanged residual conductivity of other ions present; difference of original conductance and estimated residual conductance is taken as bicarbonate conductivity. Tests on water of Rhine and tributaries near lake of Constance proved conductivity of calcium bicarbonate decreasing somewhat with increasing bicarbonate hardness from $k_{18} \cdot 10^6 = 29.8$ at 71.6 p.p.m. $CaCO_3$ to $k_{18} \cdot 10^6 = 28.4$ at 214.8 p.p.m. $CaCO_3$. Provided concentration of chlorides and nitrates is low conductance measurements may be useful for estimating total hardness and noncarbonate hardness with fair approximation.—*Manz.*

STERILIZATION

Observations on the Use of Copper and Chloramines in Water Purification. A. E. GRIFFIN. Am. Jour. Pub. Health., 27: 226 (1937). The order of application of ammonia to chlorine has been of utmost importance. It has generally been considered that the ammonia must be added first in order to prevent the formation of offensive phenols. There are times, however, when the order of application may be reversed to very good advantage. This is particularly true when it is desired to kill the bacteria as quickly as possible and at the same time produce a persistent residual. Experience has taught that the most practical ratio of ammonia to chlorine is 1:3. No hard and fast rule can be given for any single ratio of ammonia and chlorine which will be equally good under all circumstances. That the sterilizing action of the chloramines is somewhat slower than of chlorine alone is generally recognized. As stable as chloramines are they cannot under ordinary circumstances be expected to retain their chlorine forever. There is no reason, however, why chloramines cannot be reformed by adding more chlorine to combine with the remaining ammonia. The loss of ammonia may be appreciable if applied too far ahead of the chlorine, but if applied not more than a few minutes ahead in all probability the loss will be negligible. The only way to determine how much ammonia will be removed by a filter is to test for ammonia on both influent and effluent. The ammonia-chlorine process will very successfully control algae growths. There are some forms of algae which appear to grow and flourish in the presence of chlorine or chloramine residuals. Treatment with intermittent doses of copper sulphate has usually inhibited their growth but seldom stopped it entirely.—*H. E. Babbitt.*

Automatic Chlorination Solves Potential Water-Pollution Problem. ANON. Am. City, 52: 52 (1937). The small equalizing reservoir on Fisher Hill, in a suburb of Boston, Massachusetts, is fed by and emptied through the same 36-inch pipe. Generally, the flow is into the reservoir at night and out during the day, with rates of flow varying between zero and 12 million gallons per day. The reservoir is not covered and its effluent regularly shows B. coli. Manual chlorination was attempted but because of the expense of the two operators

required, the error in treatment resulting from time lag between tests and dosing, and the danger resulting from unexpected demands during unguarded periods at night, automatic chlorination was adopted. A sensitive pitot actuating device was developed for a proportional flow vacuum chlorinator. A residual of 0.07 p.p.m. is maintained on flows through the main as low as ½ foot per second. Below this amount, a small residual chlorine feed is maintained, which while chlorinating both the outflow and inflow, has no appreciable effect on the residual or taste.—*Arthur P. Miller.*

Chlorination as the Safeguard of Municipal Water Supplies. G. L. MacDonald. Eng. Cont. Rec., 50: 853 (1936). Brief description of rôle played by chlorination in elimination of water-borne disease. Graph is given showing how typhoid fever declined in Ontario with increasing use of chlorine for sterilizing water supplies. Water-borne typhoid outbreaks in Ontario are referred to briefly.—*R. E. Thompson.*

Highest Purity Obtained from Ozone Sterilization of Swimming Pool Supply of 15,000 Gallons per Hour. Eng. Cont. Rec. 50: 765 (1936). Brief description of purification plant at Manor Place Baths, Southwark, England, installed in 1935, which consists of strainer box, feeders for alum and soda, vertical pressure filters operated at 225 gallons per square foot per hour, and ozone sterilization equipment. Pool water is recirculated every 3 hours. Results have exceeded expectations.—*R. E. Thompson.*

Cumasina Procedure for Sterilization of Drinking Water. Walter Kruse and Max Fisher. Ges. Ing., 60: 10 (1937). Cuma flow apparatus and Cuma diver with silver electrodes and Sina diver with platinum electrodes for sterilization of drinking water by active silver or chlorine and use with dry or starting batteries discussed. Efficiency may be tested by observation of anodic turbidity due to precipitation of silver chloride or chlorine smell taste being eliminated by small quantities of broth, wine, juice etc. By prolonged service of sina-diver heavier chlorine solution is obtained suitable for wound disinfection etc.—*Manz.*